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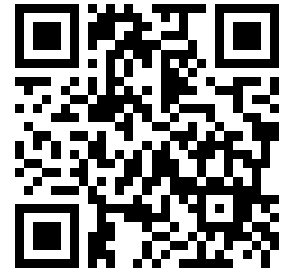

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AVIONIC INERTIAL AND RADAR NAVIGATION SYSTEMS SPECIALIST

(AFSC 32854)

Volume 6

Navigation Computers and Weapons Release Computer System

DEPOSITORY

OCT 1 9 1984

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Extension Course Institute
Air University

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Prepared by
MSgt Charles A. Ireland
(AUTOVON 868-2984)

Reviewed by
Benny A. Humphrey

Edited by
David Crawford

3300 TECHNICAL TRAINING WING (ATC)
KEESLER AIR FORCE BASE, MISSISSIPPI 39534

EXTENSION COURSE INSTITUTE (AU)
GUNTER AIR FORCE STATION, ALABAMA 36118

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Preface

DEAD-RECKONING navigation—the technique of air navigation—is essentially a problem-solving task. Dead-reckoning navigation involves manipulating such things as "magnetic heading," "true heading," "windspeed," "wind direction," and "true airspeed" in an equation which, when solved, yields the desired information.

The terms used in the equation vary in both type and form, depending on their source—an inertial, a Doppler, a stellar, or a radar navigation system. Depending on the particular navigation system into which the navigation computer is to be integrated, the computer may be an analog computer, a digital computer, or a combination of both.

In this volume, we present the theory of operation and maintenance of an inertial navigation computer, a Doppler navigation computer, and a weapons release computer.

Navigation computers, like other equipment in your AFSC, will function well only if you take care of them. To properly care for them, you must know and understand them well. This volume is designed to help you achieve this understanding.

Foldouts 1 though 9 are bound separately as a supplement. Refer to them as the text directs.

This volume is valued at 18 hours (6 points).

Material in this volume is technically accurate, adequate, and current as of June 1984.

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Doppler Navigation Computer Set

IN VOLUMES 4 and 5, you studied navigation systems that determine aircraft groundspeed and actual aircraft track angle. In this volume, you will study computers that use this information to determine the distance to go, the distance to the right or left of the desired track, and the present position in longitude and latitude.

In this first chapter, we shall discuss a computer set that is used with a Doppler sensor. In Chapters 2 and 3, you will study a computer that is used with inertial navigational equipment. In Chapter 4, you will study a general-purpose computer that is used with several items of navigational equipment. In Chapter 5, you will study a weapons release computer system.

1-1. General Description

The Doppler navigational computer set we will study in this chapter is shown in figure 1-1. It is an aircraft electronic system that computes essential flight information for a pilot.

A01. State the function of the Doppler computer set, name its components, and identify inputs and outputs of each.

The Doppler computer set receives data from external sources and computes the following navigational information:

a. The remaining distance that the aircraft has to progress along a desired track.

b. The distance that the aircraft is to the right or the left of a desired track.

c. The track-error angle, i.e., the angular difference between the desired track angle and the actual aircraft track angle.

This computer set consists of the four components shown in figure 1-1. These are (1) navigational computer, (2) control indicator, (3) auxiliary cross-track control indicator, and (4) air navigation multiple indicator. Figure 1-1 also shows a block labeled groundspeed driftangle sensor. The Doppler set that you studied in Volume 5 is this type of sensor and can be used as the source of information fed to this computer set. Note that the data fed to our computer set are groundspeed pulses, divide control signal (SMOOTH SEA), actual track, and desired track. With the exception of desired track, which is dialed into the control indicator, all of these data are supplied by the sensor.

The actual aircraft track angle is the sum of the compass heading and the aircraft drift angle. This information is obtained from the output of a differential synchro located in the groundspeed drift-angle sensor. It is fed to the control indicator, where the desired track angle is compared to the actual track angle. The difference between the two is the track-error angle. The track-error-angle signal activates the servocircuits in the computer. From the computer, the error-angle data is fed to the air navigation multiple indicator, where it is displayed by a pointer.

The groundspeed data is supplied to the computer as a series of pulses whose frequency is proportional to the aircraft groundspeed. The groundspeed signal is gated in the computer by the error-angle signal and, in SMOOTH SEA, the divide control signals in such a manner as to produce distance along-track data and distance cross-track data. The along-track data is applied to the control indicator, where it is subtracted from a preset value and read out as distance to go along track. The distance-to-go data is fed to the air navigation multiple indicator, which displays this data in digital form. The cross-track data is fed to the auxiliary cross-track control indicator. If this unit is active, the cross-track data is read out in digital form. If this unit is not active, this data is routed to the control indicator, where it is read out in digital form. Note that the track-error-angle data from the computer and the cross-track data from the control indicator are made available for use in an autopilot system.

Exercises (A01):

1. What information does the computer set generate?

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2. List the components of the computer set.

3. What is the source of the information fed to the navigation computer set?

4. Where is the track-error angle displayed?

5. In what form is groundspeed data supplied to the computer?

6. How is distance-to-go data computed?

7. Which unit or units display distance to go?

8. To which unit or units is cross-track data fed?

1-2. Functional Description of the Computer

The groundspeed data input of the computer is proportional in frequency to groundspeed. It follows that a certain number of cycles per second are equivalent to one knot and, by a system of division, the number of nautical miles traveled by the aircraft may be computed. Let us see how this is done.

A02. Cite functional characteristics of the computer set.

The division factors for the cross-track distances are determined by resolving the track-error angle into sine and cosine functions. Figure 1-2 shows the course made good (AC) by an aircraft in relation to the desired course (AB). In this case, the aircraft is off course to the right owing to wind drift or evasive action, so that it is no longer following the desired track (AB). The distance to the right (DE) is represented by the *sine* of angle "a," which is the track-error angle. The distance progressed (AD) along the intended track is given by the *cosine* of the angle ("a").

The frequency of the groundspeed input signal is equal to the groundspeed of the aircraft multiplied by the Doppler shift per nautical mile per hour. For example, if this computer is used with the sensor described in Volume 5, and the aircraft is over land, the frequency is equal to the groundspeed multiplied by 20.66. Since the Doppler shift per nautical mile in this sensor is entirely dependent upon the terrain over which the aircraft is flying, provision is made in the resolver circuits of the computer to compensate for any changes. The sensor supplies the switching (divide control) signal to the resolver to provide the required compensation. We will assume throughout the remainder of this section that the Doppler shift per nautical mile remains fixed.

Refer to figure 1-3. The groundspeed input signal is shown coupled to the Schmitt trigger, which is an amplifier and shaper circuit. After shaping, the signal

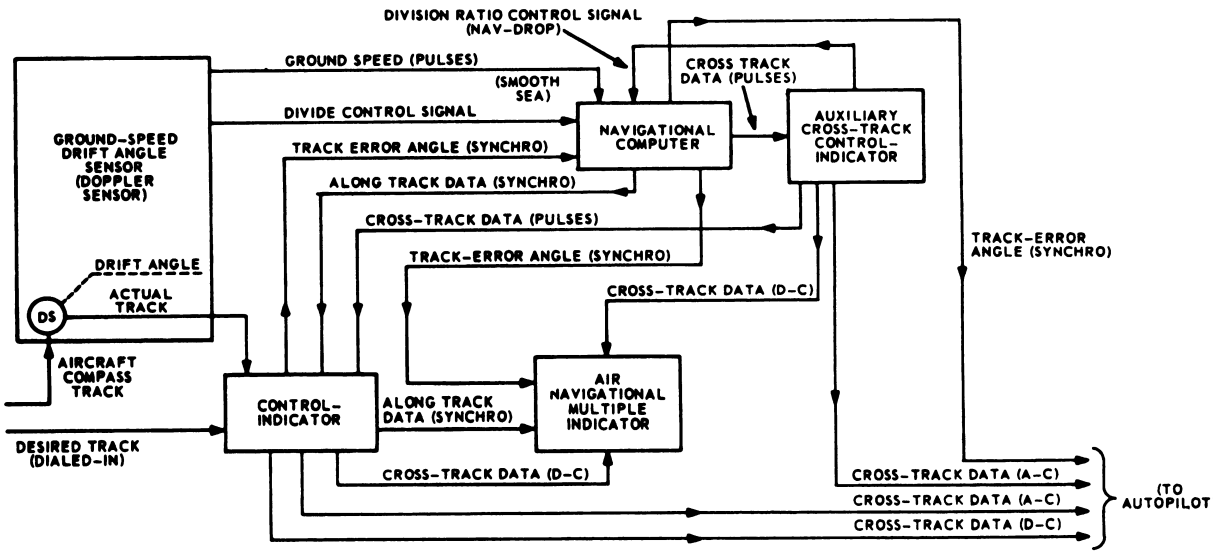

Figure 1-1. Computer set, block diagram.

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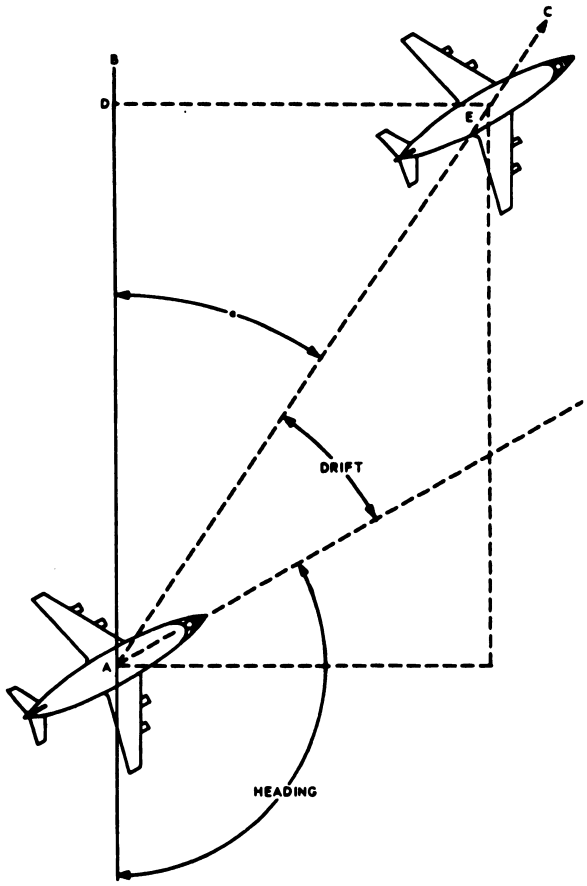

Figure 1-2. Aircraft actual track as resolved in sine and cosine.

is applied to the sine and cosine gated circuits. In the resolver, signals are derived, which open and close the the cross-track and along-track gates during periods of time proportional to the sine and cosine of the track-error angle, respectively. This signal "turns on" the sine gated amplifier and permits a number of pulses to pass to the sine binary counter, and then "turns off" the gate. The precise number of pulses passed during the "on" time is proportional to the distance of aircraft travel to the right or left of the desired track. The sine binary counter then counts down the pulses to produce one pulse for each one-tenth of a nautical mile covered. In a similar manner, the cosine circuits determine the distance covered along track; however, the output of the cosine counter is one pulse per nautical mile.

The output of the sine binary counter is amplified by the actuator and applied through the cam-operated switches to the relays of the cross-track counter. Each pulse actuates the counter through one digit. In a similar manner, the along-track data is transferred to the along-track counters.

The pulse data supplied to the computer from the groundspeed sensor contains only absolute information of groundspeed. It does not indicate left or right for cross-track signals, nor does it indicate increase or decrease for along-track signals. The set of cams shown in figure 1-3 operates switches that provide the required direction sense.

The camshaft is coupled to a standard electrical servocircuit, which drives the sine-cosine potentiometer. Since the control transformer (the error detector) of the servo is activated by the track-error-angle data from the control indicator, the cams follow the track-error angle and close the correct switches to provide the sense to the counter signals. Thus, depending upon the track-error angle, the counters are operated to read an increase or decrease in distance covered along and across the desired course.

The sine-cosine potentiometer operates the sine and cosine gate pulse-generating circuits by developing a signal proportional in amplitude to the sine and cosine of the track-error angle.

Exercises (A02):

1. What trigonometric function is used to compute cross track?

2. What trigonometric function is used to compute distance to go?

3. 100 pulses at the output of the sine binary counter represent _____ nautical miles (distance scale switch in NAV position).

4. 100 pulses at the output of the cosine binary counter represent _____ nautical miles (distance scale switch in the NAV position).

5. What is meant by adding "sense" to along-track/cross-track data?

1-3. The Computer Unit Circuit Description

Now that you understand how the computer functions as a unit, let us see how the different circuits in the computer unit perform their particular functions. As you study each circuit, turn back to the block diagram (fig. 1-3) to see where that circuit fits into the overall picture.

A03. State operating characteristics of the computer unit circuit.

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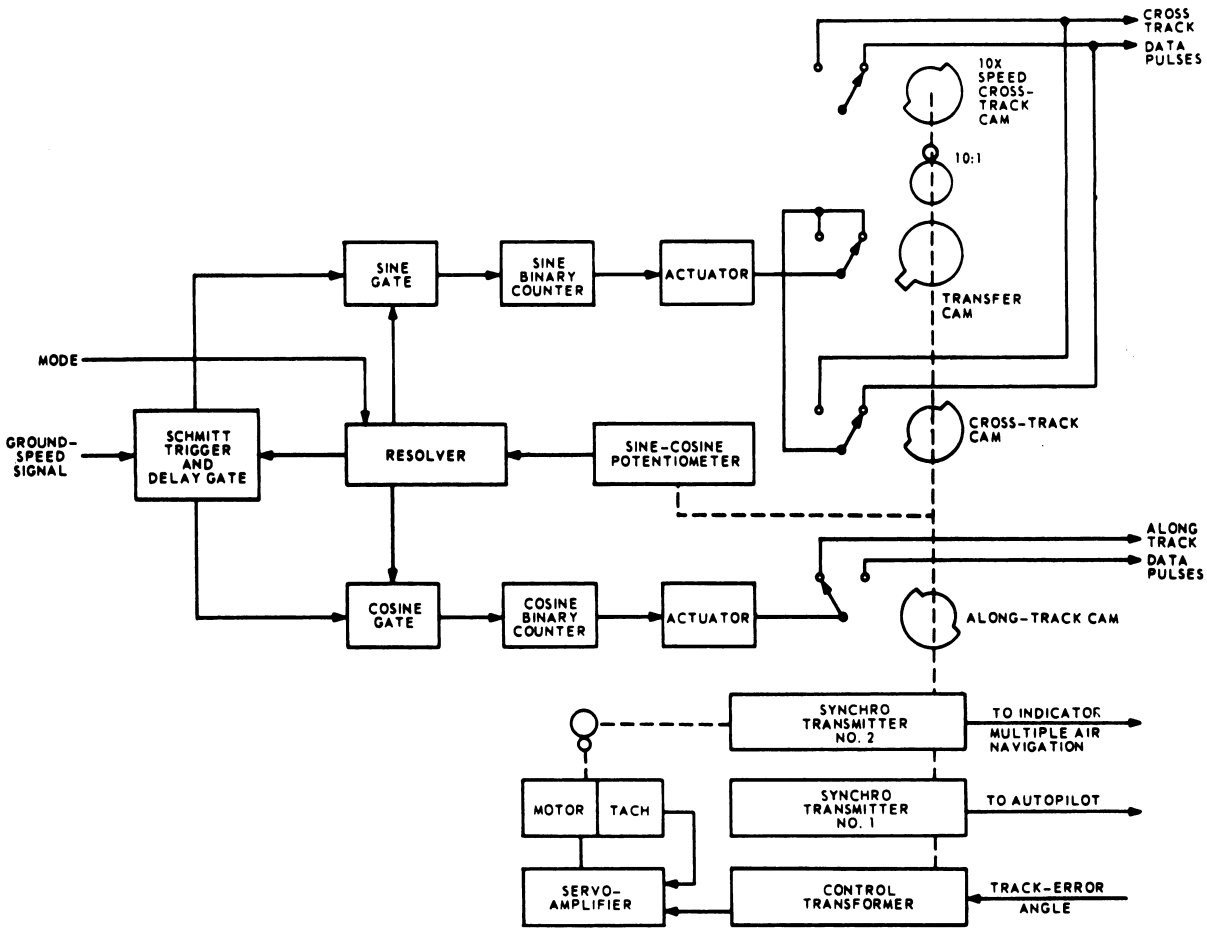

Figure 1-3. Computer block diagram.

Resolver Circuit. The resolver circuit generates the gating signals for the sine, cosine, and delay gates shown in figure 1-3. The length of the gate signals is proportional to the sine and cosine of the track-error angle. Each of the gate signals fed to the sine,cosine, and delay gates is developed in a flip-flop circuit, which is controlled by the resolver. The actual control signals are produced by a high-voltage switch circuit and multiar circuits. A multiar is a blocking oscillator that is switched on when two input voltages are equal in magnitude. The input voltages for the multiars are controlled by a clock circuit. Before discussing the operation of the resolver circuit, let us see how this clock circuit operates.

Clock circuit. The function of the clock circuit in figure 1-4 is to control the operation of the single-pole, double-throw, high-voltage switch. The flip-flop controls the high-voltage switch and, in turn, is controlled by the PNP and NPN multiars. Depending on its position, the switch applies either -50 volts or ground to the RC networks.

Assume that the switch has just operated and connects with contact 1 (ground). Capacitor C218 begins to charge from -31.5 volts toward ground potential through R1205 and R1204, and its voltage is shown in figure 1-5 as e_1. This voltage is applied to both multiars. At the same time, capacitor C219 begins to charge through diode D3 and the resistor network composed of R1210 to R301. The voltage developed at potentiometer R1207 is shown as e_5 in figure 1-5. This voltage is applied to the PNP multiar. When e_5 and e_1 are equal, the PNP multiar begins to oscillate and causes the clock flip-flop to switch. This circuit action, in turn, causes the high-voltage switch to operate, and the contact connects to terminal 2. The voltage at the arm of the high-voltage switch changes from 0 volts to -50 volts. This causes C218 to discharge. When e_1 reaches -31.5 volts, the NPN multiar operates. The output of the NPN multiar switches the flip-flop, which returns the high-voltage switch to position 1. At the same time that C218 begins its discharge, C219 discharges rapidly. The voltage at R1207 is returned to the stable voltage determined by the supply. The rapid discharge of C219 causes the PNP multiar to stop oscillations before the NPN multiar starts operating. The time constants of the two resistor-capacitor networks are adjusted so that the flip-flop produces a symmetrical square wave at the rate of 16 Hertz.

The voltage ratio of e_5 and e_1 at any instant is dependent upon the time constants of the circuit and

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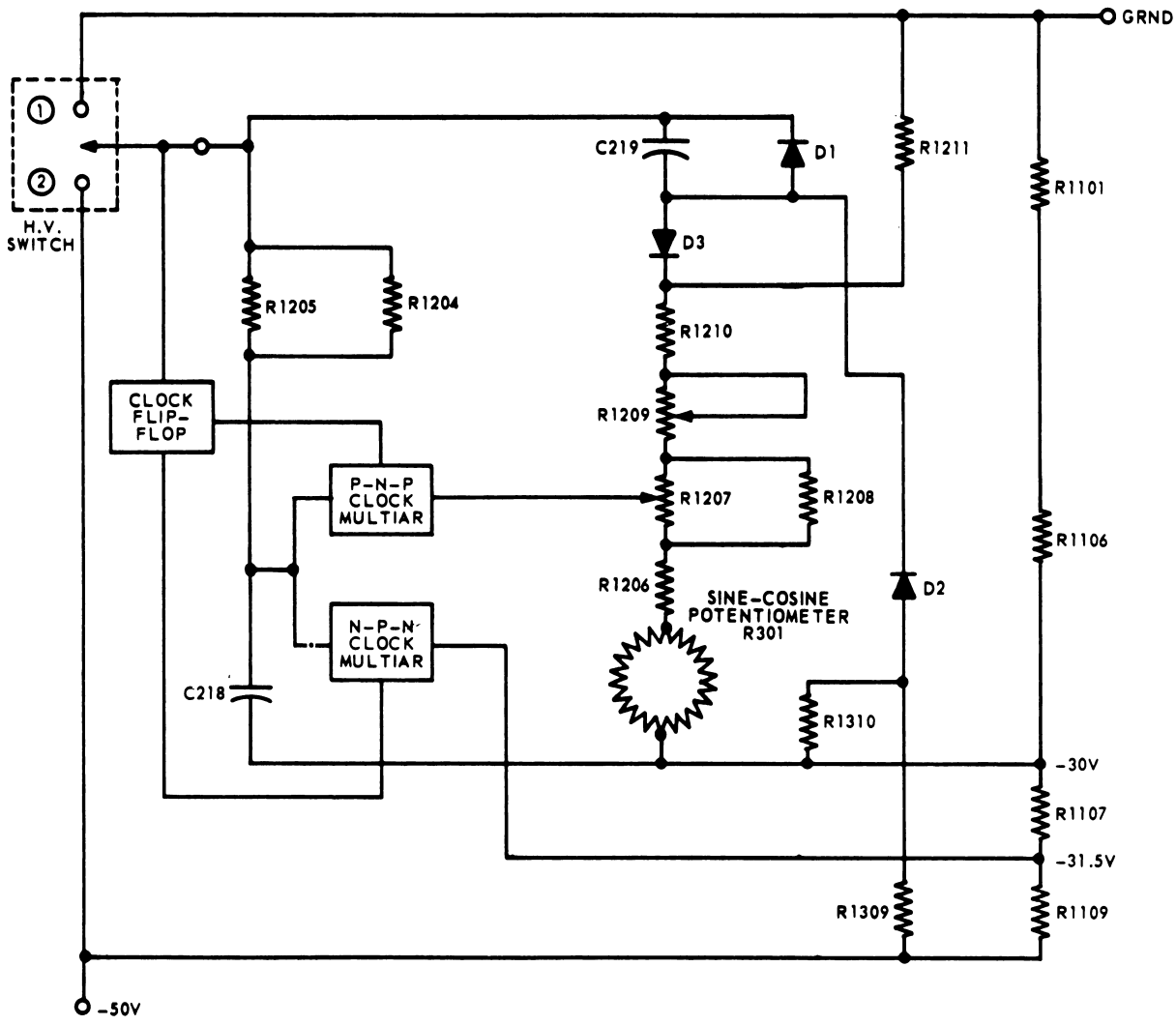

Figure 1-4. Clock circuit.

not upon the applied voltage. Therefore, the switching frequency is independent of supply voltages. This results in high stability.

Resolver operation. The operation of the resolver is explained with reference to figure 1-6. As you can see, this diagram is an extension of figure 1-4. The additional multiars switch the flip-flop circuits that provide the delay gate, cosine gate, and sine gate pulses. Resistor R301 is shown as a back-to-back potentiometer, which is servo driven to follow the track-error angle. One output of R301 controls the sine multiar, and the other output controls the cosine multiar (The operation of the clock circuit flip-flop and multiar is discussed later in this section.) In figure 6, the multiars are labeled CC1 (coincidence circuit 1) through CC5. Assume that the high-voltage switch has just operated and contact is made with terminal 1. This results in a signal, developed by the RC network which switches the flip-flops (not known) feeding the various gates. When this occurs, the sine and cosine gates are turned off. Turning the delay gate off prevents the groundspeed signal from being passed to the sine and cosine gates. At the same time that the HV switch makes with contact 1, capacitors C218 and C219 begin to charge. Voltage e_1 (fig. 1-7) starts toward its maximum value. When e_1 leaves the -31.5 volts, NPN multiar (CC1) stops oscillating. (CC1 was placed in operation during the previous half-cycle.) This action prepares the clock portion of the circuit for switch action when e_1 reaches e_5.

When voltage e_1 reaches the value e_2 (-30 volts), PNP delay multiar CC2 starts oscillating. The output signal of the delay multiar operates the delay gate flip-flop. The output of the flip-flop, in turn, causes the delay gate of the Schmitt trigger and gates to operate. Refer back to figure 1-3. At this point, the groundspeed signal is fed through the sine and cosine gates to the binary counters.

As voltage e_1 continues to increase, it reaches the potentials e_3 and e_4, which are taken from the sine and cosine potentiometers. The precise point where e_1 meets e_3 and e_4 depends upon the setting of R301, and

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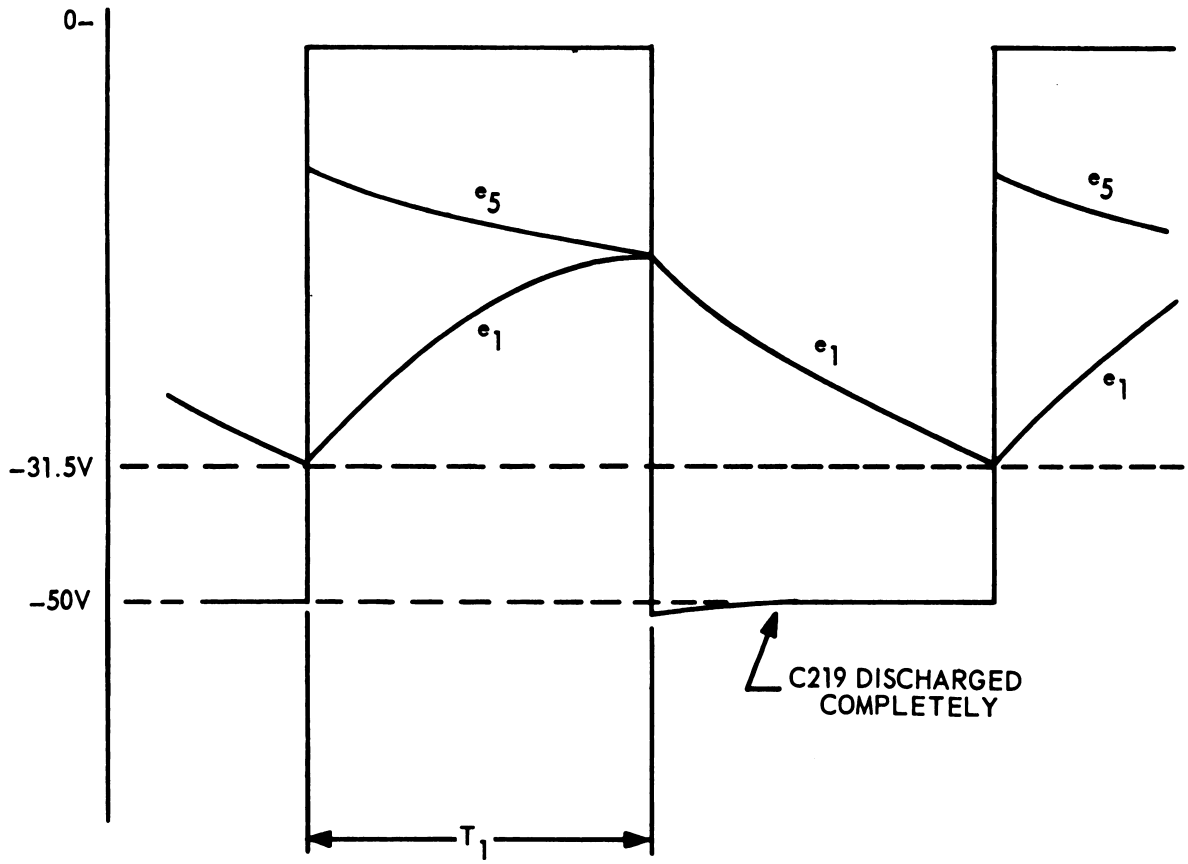

Figure 1-5. Clock waveforms.

this setting depends upon the track-error angle. When e_1 is equal to e_3, sine multiar CC3 oscillates and causes the sine flip-flop to switch. The sine flip-flop causes the sine gate to close and stops the passage of the ground-speed pulses to the sine binary counter. Similarly, when e_1 reaches e_4, the cosine gate closes.

When e_1 reaches e_5, PNP multiar CC5 operates and causes the clock circuit to switch. C218 starts to discharge and e_1 begins to drop. At the same time, C219 rapidly discharges, and the voltages distributed along the resistor network R1210 through R301 return to their original stable value. As e_1 passes through the various voltages, all of the PNP multiars stop oscillating in preparation for the next cycle. When e_1 reaches –31.5 volts, the NPN multiar oscillates and causes the high-voltage switch to operate, thus starting a new cycle. Figure 1-8 relates the time sequence of the various output waveforms that result from the operation of the resolver.

The multiar and flip-flop. Refer to figure 1-9 for the PNP multiar and flip-flop circuit. Examination of the circuit will show that, if diode CR2 is removed and diode CR1 is shorted, transistor Q1 will operate as a form of blocking oscillator. If the diodes are replaced, they are seen to be in series with input voltage e_1 at T_1, and e_2 at the anode of diode CR2. When voltage e_2 exceeds e_1, diode CR1 is reverse biased and, therefore, represents a high impedance in the blocking oscillator feedback path from the emitter to the base of Q1. Therefore, the circuit does not oscillate. However, when e_1 exceeds e_2, diode CR1 is a low impedance and diode CR2 is a high impedance, and the circuit oscillates. When e_1 equals e_2, no current flows in the diodes. Any pulse at the emitter of Q1 is increased 2:1 by transformer T1, then attenuated 2:1 by the diode impedances (roughly 10K), and the circuit just begins to oscillate as e_1 equals e_2. Under these conditions, the loop gain is unity and the oscillations are self-sustaining.

The first negative-going pulse at the collector of Q1 is the one in which we are interested. The oscillations of Q1 are connected by capacitor C5 to the base of Q2, a common emitter circuit. The positive signal output is clipped by Zener diode CR4. This prevents any stray oscillations from riding in on top of the quiescent bias on Q3, which would cause erratic operation of the flip-flop circuit.

A PNP multiar is sensitive only in detecting coincidence between voltages e_1 and e_2 when e_1 is an increasing voltage. Therefore, when a decreasing voltage is to be compared to a fixed voltage, an NPN multiar must be used. In this case, the diode polarities are reversed and an NPN transistor is used. An NPN multiar is used in the computer resolver circuits, which have already been described.

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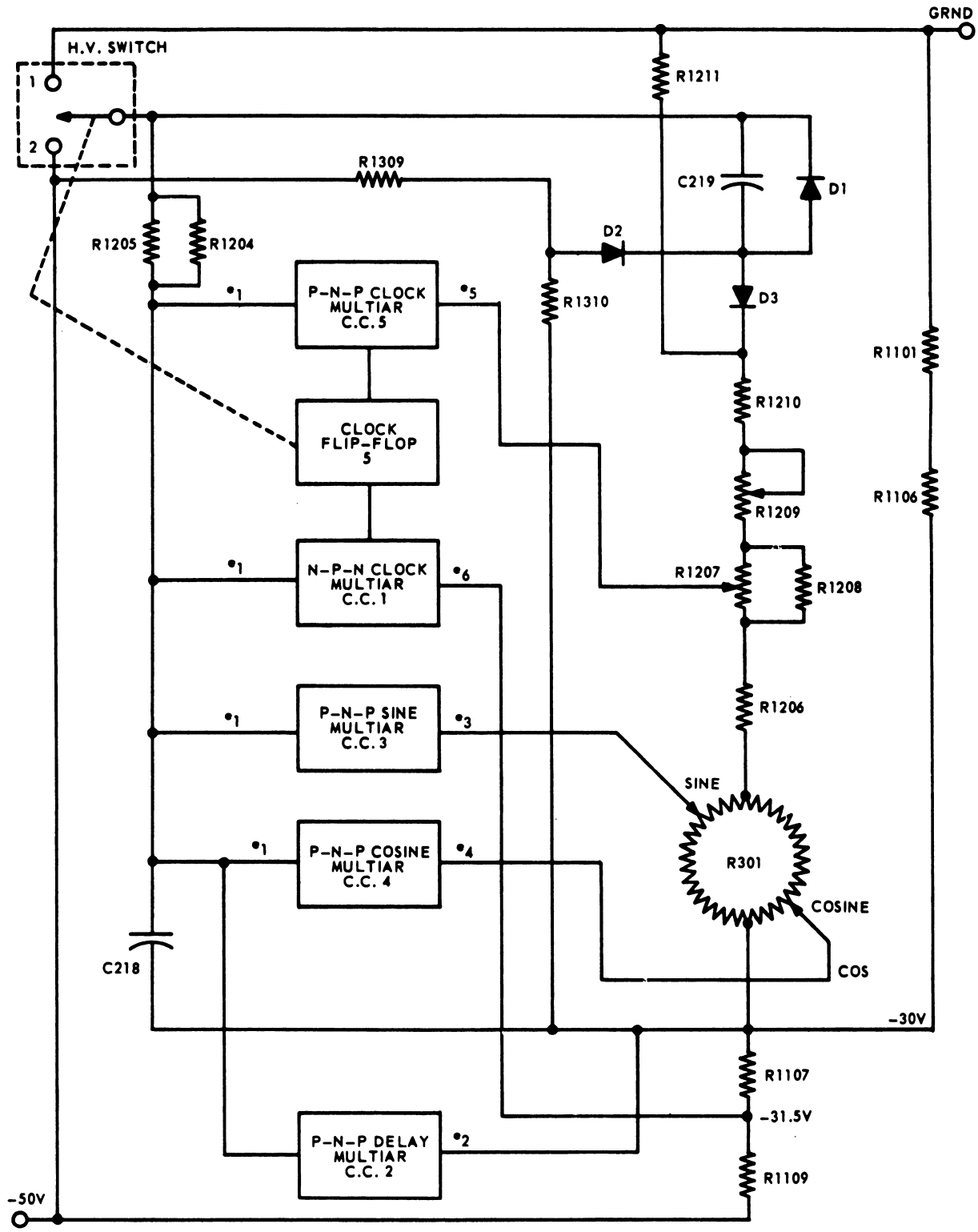

Figure 1-6. Resolver.

The high-voltage switch. Refer to figure 1-10. The purpose of the high-voltage switch has already been described. It consists of five transistors and three Zener diodes, which act as regulators. Initially, consider Q1 to be a common collector configuration that acts as an emitter follower. When the NPN multiar fires, it generates a large positive pulse, which flips the clock flip-flop. The output of the clock flip-flop is applied directly to the base of Q1 in the HV switch which, in turn, drives the base of Q2 toward +12 volts. The

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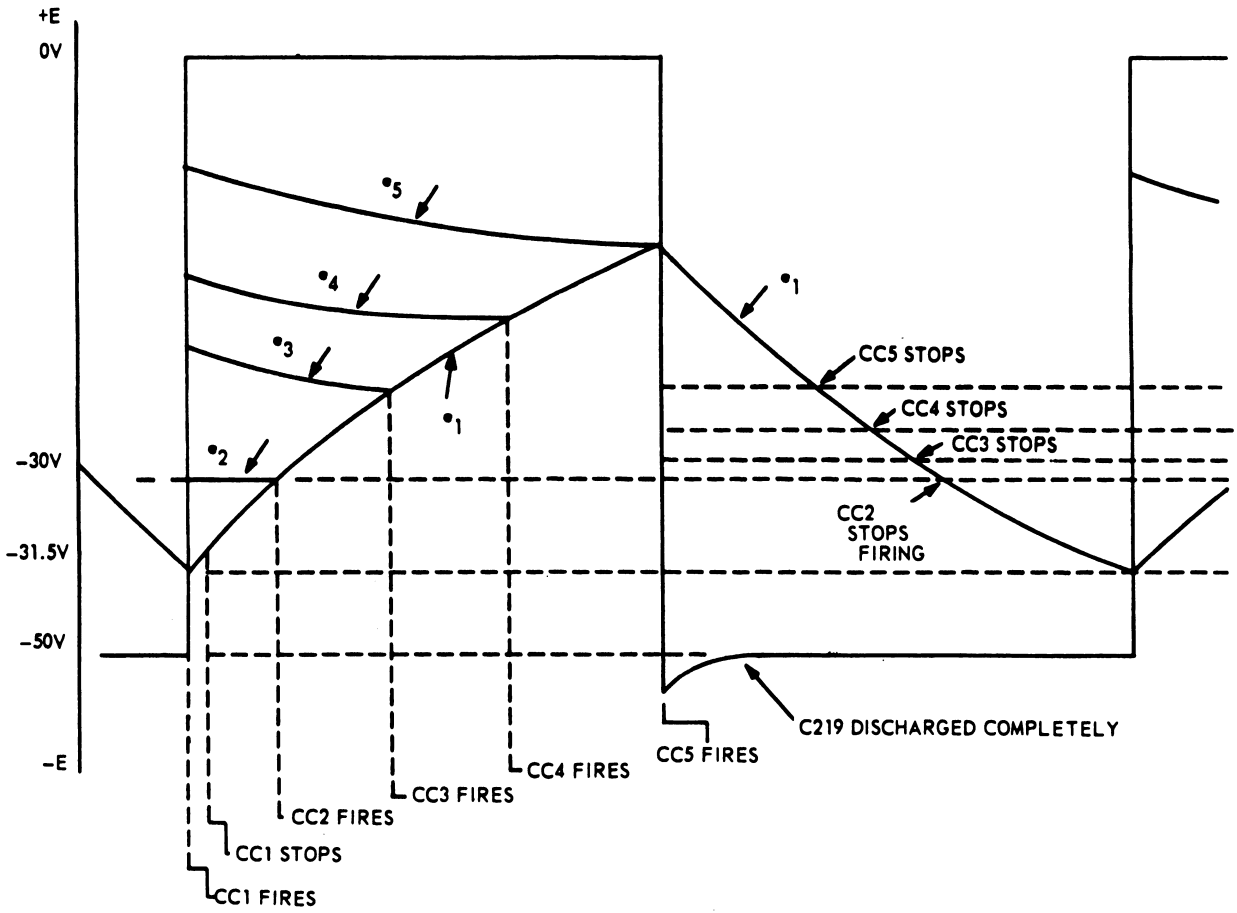

Figure 1-7. Resolver waveforms.

emitter of Q2 is held at -4 volts by Zener diodes CR1, CR2, and CR3 and, since the base of Q2 is now much more positive than the emitter, Q2 turns on. Q3 turns on when its base is carried sharply down because of its connection to the collector of Q2 via R5. At the same time, Q4 turns on since R8 is also connected to the collector of Q2. When Q3 is turned on, it drives the base of Q5 sharply to ground and Q5 cuts off. Since the coincidence circuit bridge is connected to the collector of Q4 and to the emitter of Q5, it swings from -50 volts to ground. This sharp rise in voltage triggers the sine, cosine, and delay flip-flops, and so closes the delay gate and opens both sine and cosine gates simultaneously. When e_5 meets e_1 (fig. 1-5), the PNP multiar oscillates and reverses the state of the clock flip-flop. The change in the output of the flip-flop causes a sharp negative pulse, which is conveyed to the base of Q2 by Q1. This cuts off Q2 which, in turn, cuts off Q3 and Q4 and causes Q5 to saturate. This, in turn, switches the coincidence circuit bridge from ground back to -50 volts. The cycle then repeats itself at approximately 16 Hertz.

Exercises (A03):

1. What is the purpose of the resolver circuit?
2. Under what condition does a multiar operate?
3. In the navigation computer set, for what purpose is a multiar used?
4. What circuit causes the high-voltage switch to change states?
5. If the high-voltage switch ouput is at 0 volts, what is the sequence of the clock multiars' firings?
6. What determines when the sine and cosine multiars operate?
7. Which pulse from a multiar is used?

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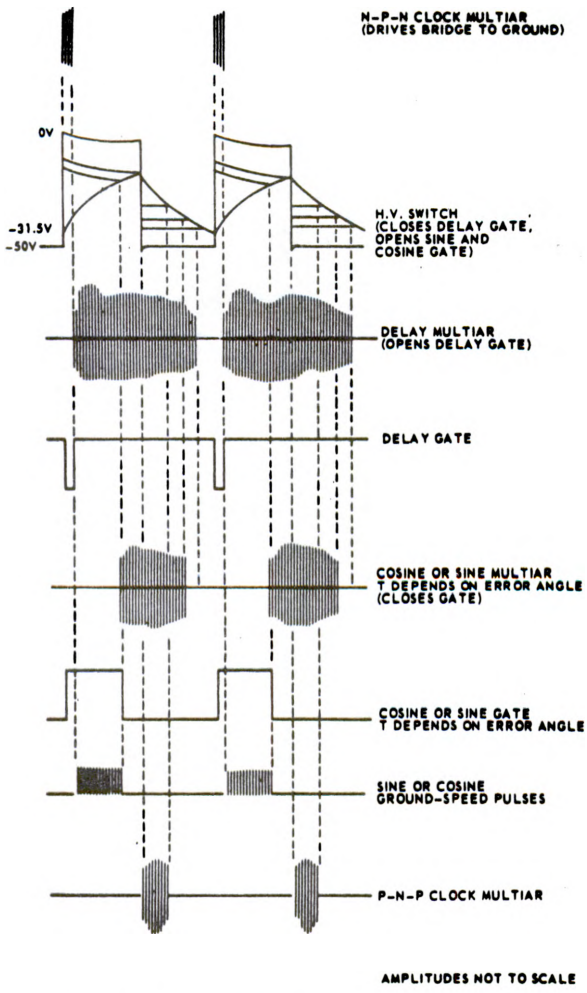

Figure 1-8. Relative sequence of resolver waveforms.

8. What is the difference between a PNP multiar and an NPN multiar?

9. What is the frequency and amplitude of the output from the high-voltage switch?

A04. Cite the purpose of the Schmitt trigger and gate circuits and the length of time the delay gate remains closed.

Schmitt Trigger and Gates. Refer to figure 1-11 for the Schmitt trigger and gates. Also, turn back to figure 1-3 to see where these circuits fit in the computer. It is the function of the Schmitt trigger and delay gates to direct the sine and cosine signals to the along-track and cross-track binaries. The gate circuits act as switches to accomplish this function. The delay gate closes the signal path for a short interval to insure that the beginning of the sine and cosine gates are together. The sine gate is closed by the sine coincidence circuit, and the cosine gate is closed by the cosine coincidence circuit.

The Doppler cycles, as received by the computer, consist of ill-defined waveforms having slow rise times. To obtain a constant well-defined square waveform of a frequency equal to that of the Doppler ground speed, a Schmitt trigger is used.

Q1 and Q2 form the modified Schmitt trigger circuit. R1 and R2 determine the bias applied to the base of Q1. Q1 is initially on, and Q2 is off. As the input signal drives the base of Q1 positive via C1, a point is reached where Q1 cuts off. This will always be at a constant potential, which is determined by R1 and R2. When Q1 cuts off, the collector voltage falls almost instantaneously to a low value. Q2, which has been cut off by the base bias applied by R6, R5, and R4, saturates, since its base is pulled to a low voltage level by the sudden drop in the voltage at the collector of Q1. This switchover is further speeded up by C2, which passes the sharp drop on the collector of Q1 to the base of Q2. This condition, Q1 cut off and Q2 saturated, is maintained until the input signal falls in amplitude to a point where the base voltage of Q1 is low enough to cause it to saturate. The system immediately reverts to the original state much as a flip-flop circuit. The output waveform at the collector of Q2 is, therefore, a constant amplitude square-wave signal of a frequency determined by the input signal from the Doppler. The Schmitt trigger output signal is coupled and differentiated by C3 to the base of delay gate transistor Q3.

Delay gate transistor Q3 is generally in a state of conduction so that the groundspeed frequency is freely passed. However, when the delay pulse occurs from the delay flip-flop, the emitter of Q3 is driven sharply negative for 2.5 milliseconds (ms). At the same time, the cosine and sine gates are opened by a fast rise time positive pulse on the emitters of Q5 and Q6. Zener diode CR3 limits the positive gate on the emitter of Q3 to approximately 7 volts, thereby clipping any spurious pulses. While the delay pulse is in existence, no groundspeed pulses are passed through transistor Q3; so even though the sine and cosine gates may be opened, there are no output pulses from Q5 and Q6 to the sine and cosine binaries. Therefore, when the delay pulse ceases, delay gate transistor Q3 opens so that pulses reach Q5 and Q6 at exactly the same time. These gate transistors for cosine and sine close on completion of their appropriate times, as determined by the sine-cosine potentiometer and coincidence circuits. The output of the delay gate transistor is differentiated and amplified by Q4. The output of Q4 is coupled via diodes CR1 and CR2 to cosine gate transistor Q5 and sine gate transistor Q6, respectively. Diodes CR1 and CR2 allow direct pulse coupling to Q5 and Q6 and thus isolate the collector of Q4. The Schmitt trigger

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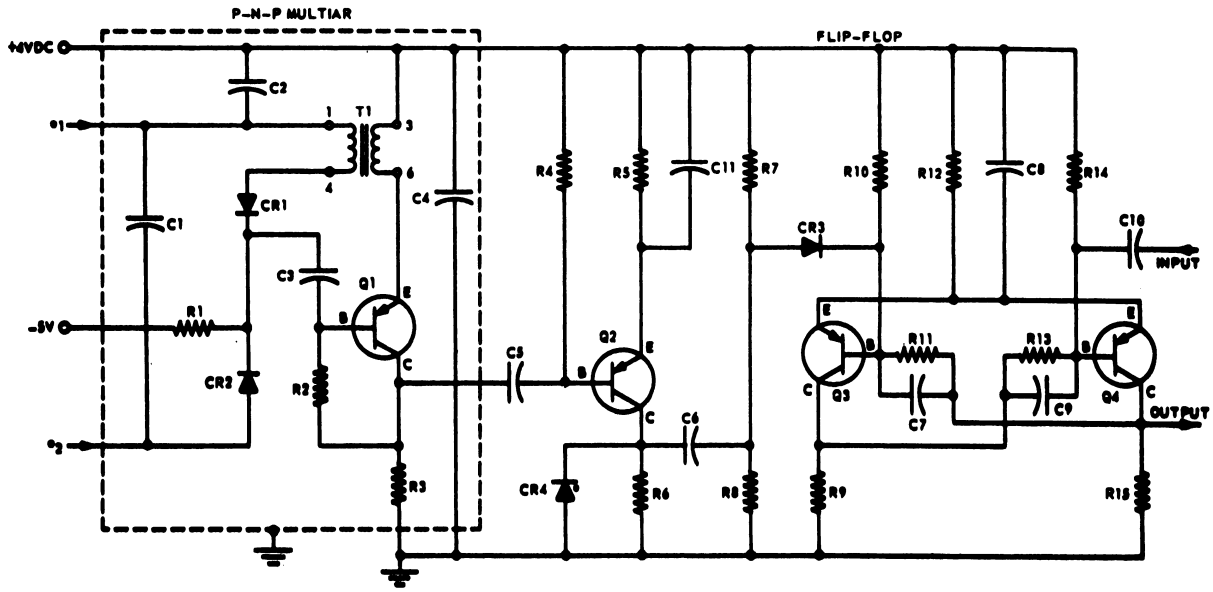

Figure 1-9. PNP multiar and flip-flop.

and gate circuits are powered by a regulated +12-VDC supply.

Exercises (A04):

1. What is the purpose of the Schmitt trigger circuit?
2. State the purpose of the gate circuits.
3. How long is the delay gate closed?

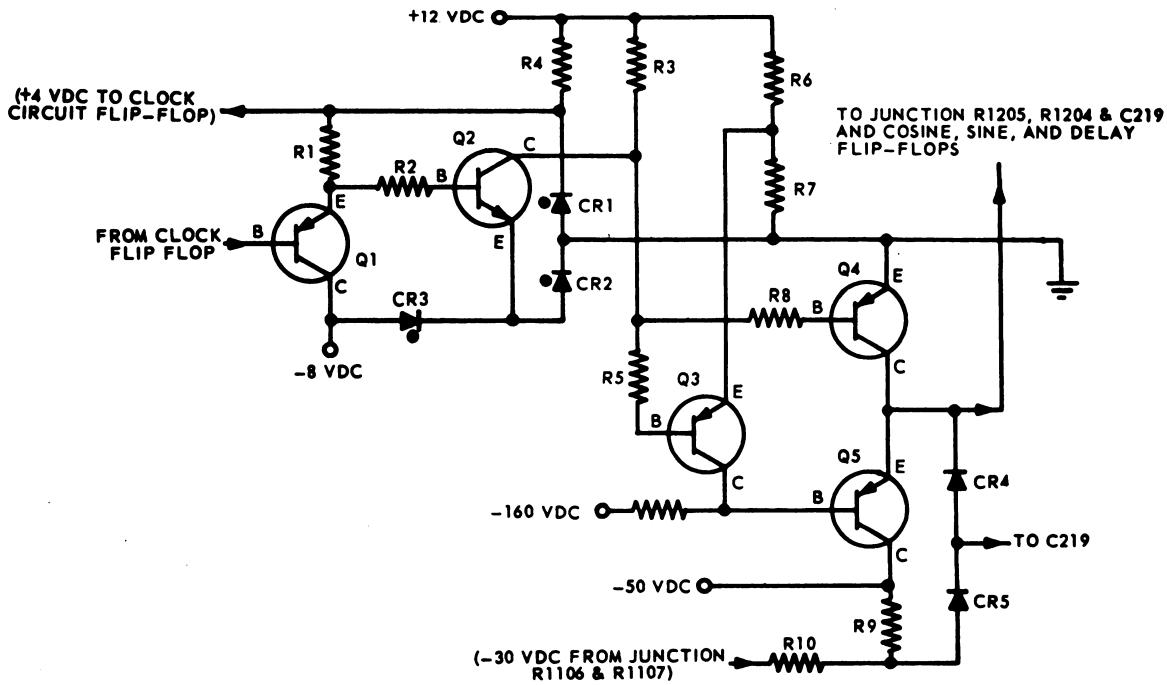
+12 VDC
(+4 VDC TO CLOCK CIRCUIT FLIP-FLOP)
FROM CLOCK FLIP FLOP
-8 VDC
TO JUNCTION R1205, R1204 & C219 AND COSINE, SINE, AND DELAY FLIP-FLOPS
-160 VDC
-50 VDC
(-30 VDC FROM JUNCTION R1106 & R1107)
TO C219

Figure 1-10. High-voltage switch.

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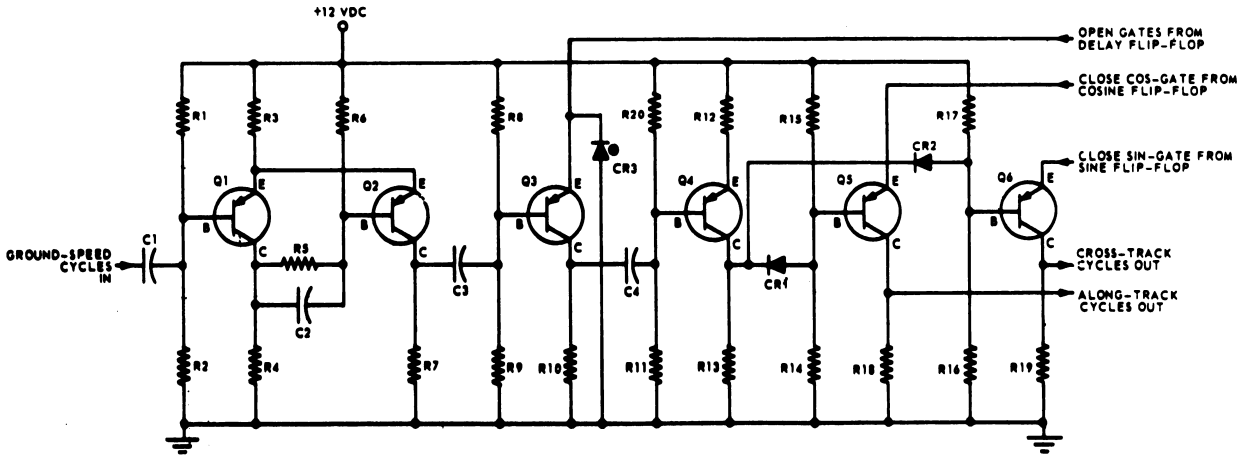

Figure 1-11. Schmitt trigger and gates.

A05. Define tri-binaries and cite operating characteristics.

The Tri-Binaries. The basic counting circuit used in the sine and cosine counters is called a *tri-binary*. Refer to foldout 1 and again to figure 1-3. Each tri-binary consists of three identical flip-flop circuits. Transistors Q1 and Q2 form the first flip-flop circuit. This circuit has two stable states—transistor Q1 saturated and transistor Q2 cut off and vice versa. Cross-coupling resistors R16 and R17, together with common emitter resistor R13, permit triggering from one state to the other. The input pulses from the Schmitt trigger and gate are coupled into the first tri-binary via C1. The two diodes, CR1 and CR2, are each returned to the junction of R1 and R4, which gives them a fixed reference. Assume that initially Q1 is on and Q2 is off. Then diode CR2 has a lower reverse bias than CR1, which is connected to the off transistor, Q2. Hence, the first positive pulse of the groundspeed pulses reaches the "on" transistor and begins the action that finishes in the other stable condition of the flip-flop. The next pulse reaches the new "on" transistor and returns the flip-flop to its original state. The cycle repeats itself and so binary counter action occurs. By virture of the polarity of the diodes, only positive pulses can trigger the flip-flop. Therefore, for each two positive pulses entering via C1, there is only one positive pulse at the collector of Q2 (i.e., each time Q2 is on). When the three flip-flops are cascaded, a scale division of 8 is obtained. The tribinary board is connected so that the input and output of flip-flop numbers one and two are brought out on external terminals while the input of flip-flop three is internally connected to the output of flip-flop two. The input of flip-flop three is brought out as well. By bringing the bases of transistors Q2, Q4, and Q6 out on separate external terminals, it is possible to incorporate a feedback system that can be used to change the division ratio of the tri-binary board from 8 to several other lower scaling factors. This is done by feeding the output of any other flip-flop to the feedback terminal blade of any previous state. In practice, it is desirable to make the step over more than one flip-flop to insure stability. This feedback network consists of a resistor in parallel with a diode and these in series with a capacitor. The feedback path is from the flip-flop output, through the capacitor to the parallel resistance and diode. The diode forms a high impedance, since it is normally reverse-biased by the low-collector voltage on the output transistor. However, when the output transistor goes up in potential coincident with the arrival of a groundspeed pulse, the diode becomes a very low impedance and so triggers the input flip-flop. This results in one extra pulse at the output. In this way, the output flip-flop adds a number of pulses equal to its output X pulses with the result that fewer X pulses are required at the input to give the same output.

The Doppler system has a klystron frequency of 8800 MHz and, in conjunction with the antenna configuration, provides a groundspeed frequency of 20.66 Hertz per knot when the aircraft is flying over land. This means that in 1 hour the Doppler output consists of 74,376 cycles (20.66 × 3600 = 74,376) for each nautical mile traveled. Therefore, it is necessary only to divide the input frequency by this number to achieve one pulse per nautical mile traveled. The resolver circuit has shown how the sine and cosine gates are generated. For simplicity of division, the periodic rate of the HV switch and clock multiars has been chosen to yield a maximum gate length of approximately 41.68 percent when the angle cosine equals 1; i.e., when there is no cross track and the actual track therefore equals desired track. This means that approximately 58.32 percent of the division has already been accomplished. The remainder of the division (41.68 percent of the total 74,376 cycles) is handled by tri-binaries. The binaries, therefore, must divide by a scale factor of 30,000. By using five boards consisting of three binaries each and one binary of a sixth board, we find that the division

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factor is 65,536. However, we require a division factor of 30,000, which is 35,536 less than that obtained. By using a feedback network as previously explained, the circuit is modified so that only 30,000 pulses are required to give one output pulse from the binary chain. We now have a binary chain which divides by 30,000. This chain then, in conjunction with the cosine gate, delivers one pulse for every 74,376 pulses delivered by the Doppler as groundspeed. The cross-track binaries are developed similarly but since a pulse is required every one-tenth of a mile traveled (sine), the binaries used divide by 3000.

When the aircraft is flying over water, the Hertz per knot drops by a factor of 1.25 percent. To make this change, the maximum gate length available in the resolver is increased by approximately one-half percent; thus, the overall division ratio of along track and cross track is changed from 74,376 to 73,760. This is done by shunting a resistor into the power supply to raise the -50-volt supply to the HV switch; this reduces the sine and cosine gate lengths.

When the Doppler system flies over extremely smooth water, it may go into the SMOOTH-SEA mode. When this happens, the groundspeed becomes 6.88 Hertz per knot. Therefore, the along-track and cross-track binary division ratios must be changed. The new overall division ratio becomes 6.88 × 3600 = 24,768. Since approximately 41.86 percent of this division is supplied by the resolver gates, the binaries must divide by 10,000. This is done by using the same binary boards as in land and operating relays to switch new feedback circuits into the counter. Similarly, the cross-track binaries must be changed so that they divide by 1000 and yield a pulse every one-tenth of a mile traveled in cross track. The relays that do the switching are actuated by the Doppler system as it changes from mode to mode.

When the *distance scale* switch on the auxiliary cross-track counter is placed in the DROP position, relays are actuated and the feedback networks and binaries are rearranged in along-track and cross-track channels so that the cross track yields 1/100-mile counts and the along track yields 1/10-mile counts.

Exercises (A05):

1. What type of circuit is a tri-binary?

2. How many output pulses are generated from the cosine binary counter with an input of 60,000 pulses?

3. How are the sine and cosine gate lengths reduced from SMOOTH-SEA operation?

A06. Cite operating characteristics of components in the actuator circuit.

The Actuator. Refer to figures 1-12 and 1-3. The output signals of the along-track and cross-track binaries are not of sufficient power to drive the mechanical counters. For this reason, it is necessary to provide power amplification. This is done by the actuator. Input transistor Q7 acts as an emitter-follower and applies its output to the base of Q4. The input to the base of transistor Q7 is produced by the binary counters and can be either of two states—a low or a high condition. Transistors Q4 and Q2 form a DC Schmitt trigger circuit, and the output of Q2 is fed through capacitor C1 and diode CR1 to the base of Q3. Transistors Q1 and Q3 form a monostable multivibrator. The output of Q3 is fed through transistor amplifier Q5 to transistor Q6. Transistor Q6 simply acts as a single-pole switch to actuate the mechanical counters. In the quiescent state, transistor Q3 is conducting, Q1 is cut off, and diode CR1 has a small forward bias, which insures rapid response to positive-going signals from transistor Q2. Negative-going signals do not affect the multivibrator, since the diode acts as an open circuit for negative signals.

The Schmitt trigger has two stable states. Let us assume for this description that transistor Q4 is conducting while Q2 is cut off. This condition occurs when there is a low-voltage input at the base of Q7. When the input at the base of Q7 goes high, the voltage applied to the base of Q4 goes high (positive) and Q4 cuts off. The voltage at the base of Q2 decreases, and the voltage at its emitter increases. Hence, Q2 is forward-biased and conducts. This results in a positive-going voltage at the collector of Q2, which triggers the multivibrator.

The resultant switching action of the multivibrator causes Q3 to cut off and Q1 to conduct. This condition remains as long as the discharge of C2 is adequate to hold Q3 cut off. As a result of the operation of the monostable multivibrator, a negative-going pulse is produced at the base of Q5. The output signal of Q5 is applied to Q6 and makes Q6 conduct. The low resistance of Q6 (while it is conducting) effectively results in a ground at its collector, which actuates the mechanical counter.

When the input signal of Q7 returns to the low value, the Schmitt trigger is restored to its initial state. However, because of CR1, the negative-going voltage developed at the collector of Q2 does not trigger the multivibrator. Capacitors C5, C6, and C7 reduce the effects of undesired transients. C3 and C4 are speedup capacitors. Diode CR3 is provided for the discharge of coils in the mechanical counters. The cross-track actuator is identical to the along-track actuator, and they are interchangeable.

Exercises (A06):

1. What is the purpose of the actuator circuit?

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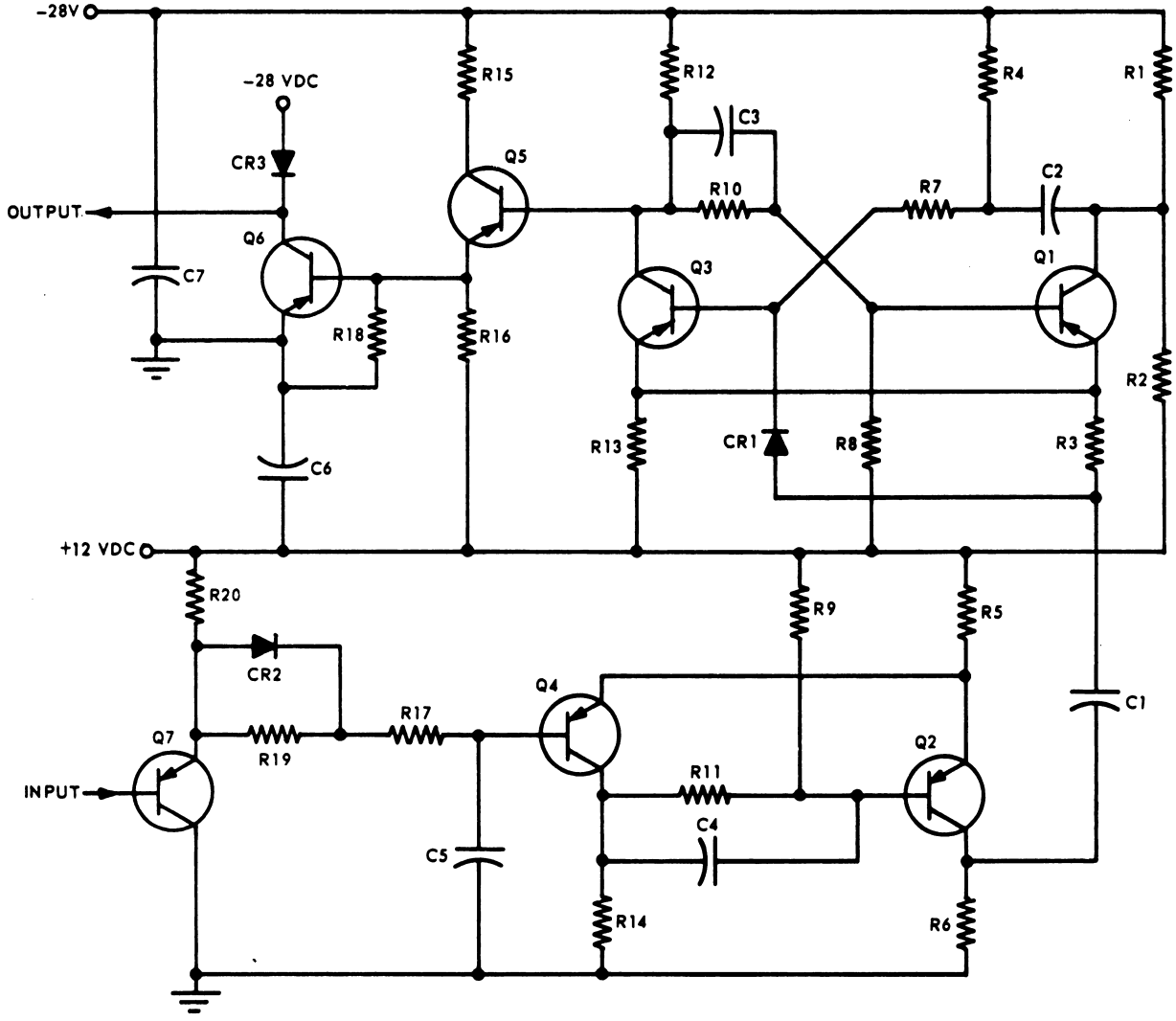

Figure 1-12. The actuator.

2. Where is the output of Q7 (fig. 1-12) applied?

3. Which two transistors make up the Schmitt trigger (fig. 1-12)?

4. The transistor _____ actuates the mechanical counters.

A07. State the purpose of pertinent circuits of the servoamplifier.

The Servoamplifier and Motor. Refer to figure 1-13. The composite compass signal arriving from control transformer CT1 in the track resolver drive (see fig. 1-14) consists of the actual compass information, the differentials set in by the Doppler drift information, and the desired track. The function of the servoamplifier is to provide the necessary control and power to drive a motor. This motor, in turn, drives the sine-cosine potentiometer and its associated cams and switches so that they are accurately aligned with the compass information as received. Thus, the track resolver shaft is always aligned in such a way as to indicate track-error angle. The output of the control transformer is zero when properly aligned with the compass information.

If the compass turns in a positive direction (main cam turns clockwise), the error voltage developed in the CT rotor is of a leading phase; a negative rotation gives a lagging phase. This signal is coupled to the base of transistor Q1 via R1 and C1. Q1 is a common collector configuration with a high-input impedance and a low-output impedance. The output is coupled to Q2 via C2, which is large in order to pass the low

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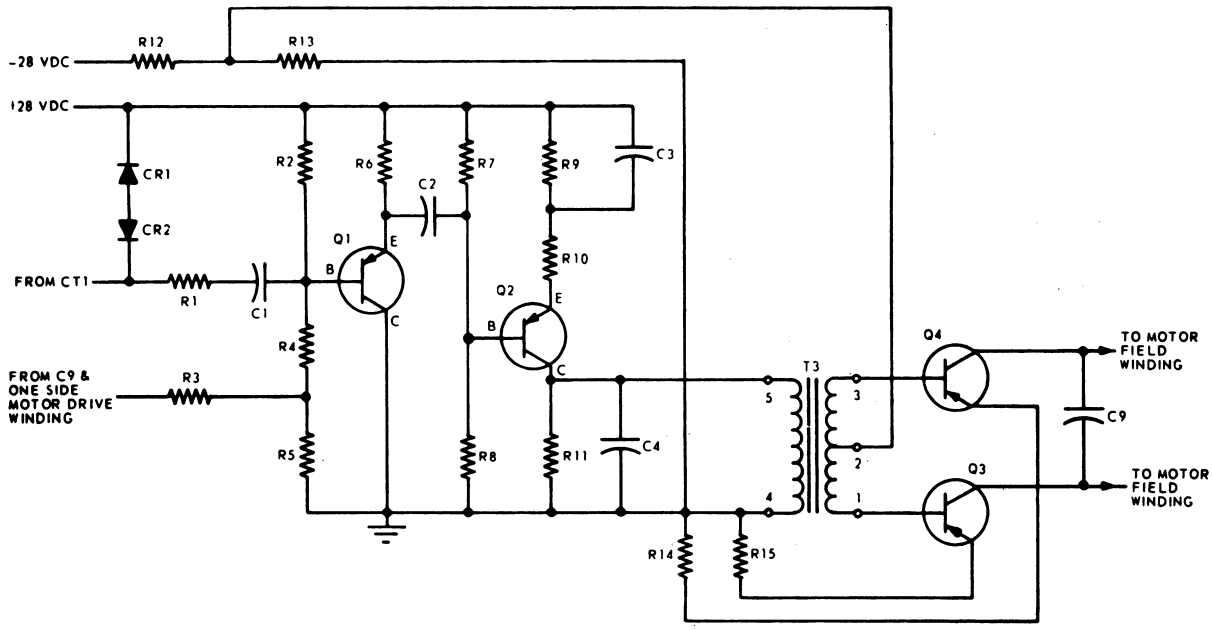

Figure 1-13. Servoamplifiers.

frequency. The output of Q2 is applied to a phase detector and power amplifier in the power supply. Resistor R9 sets the emitter bias for Q2, and capacitor C3 provides a low-impedance path for error signals.

In figure 1-13, transistors Q3 and Q4 make up a phase detector power amplifier circuit. Depending on the phase of the signal applied to transformer T3, either Q3 or Q4 conducts. The collectors of these power transistors are connected to the control winding of the motor generator in the track resolver drive (fig. 1-14). By controlling the phase of the current in this winding, Q3 and Q4 control the direction the motor rotates. By a gear train, the motor turns the control transformer shaft until the output of the control transformer rotor is zero. In this manner, the servoamplifier system maintains the track resolver

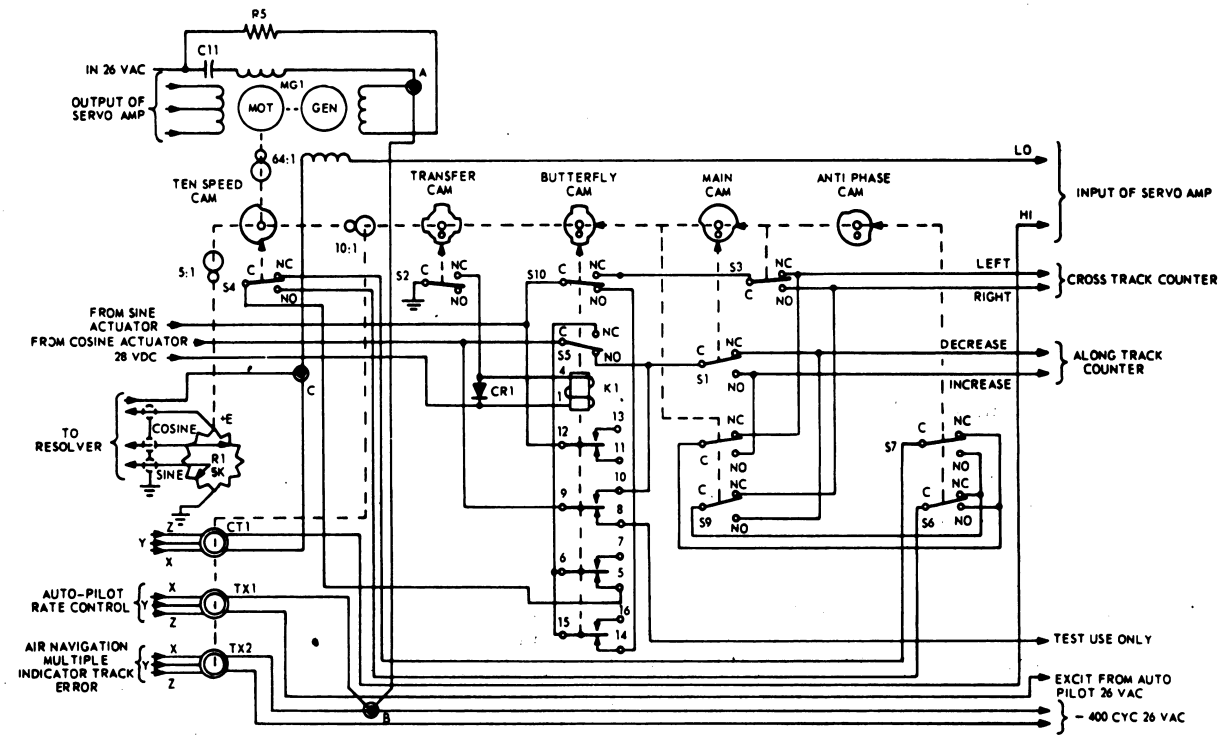

Figure 1-14. Track resolver drive.

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shaft in proper relationship with the compass. Resistor R3 (in fig. 1-13) provides some negative feedback, which tends to stabilize the system. The motor generator has a feedback winding that is connected in series with the output of the servoamplifier.

This feedback winding, together with the mechanical coupling, provides feedback to stabilize the system. Resistor R5 (see fig. 1-14) in the track resolver drive limits the current through the generator field winding and thus determines the amount of tachometer feedback injected. The feedback damps the system and prevents hunting. The value of R5 is selected for maximum sensitivity to insure accurate CT zeroing and yet provide maximum antihunt action. Capacitor C11 (fig. 1-14) provides a phase shift in the motor field so that maximum power transfer is obtained from the control windings.

If the servoamplifier in figure 1-13 fails at any time, the CT rotor will no longer be aligned with 0 output. If the input to the servoamplifier is of a low impedance, the off-zero current of the rotor is quite high and an out-of-phase flux is reflected back into the aircraft synchro system. In this circuit the input impedance is kept very high by the use of transistor Q1 in a common collector circuit. The input impedance is further raised by diodes CR1 and CR2, together with R1 and C1. The input impedance is therefore so high that should the servosystem fail, no current flows in the CT rotor. This protects the aircraft synchro system.

Exercises (A07):

1. In figure 1-13, what is the purpose of the input through R3?

2. In figure 1-13, what is the purpose of keeping the input impedance of Q1 high?

A08. State the purpose of the track resolver drive and related items, and explain what happens in a given flight situation.

The Track Resolver Drive. The track resolver drive (TRD) provides the cams, switches, relay, and synchro systems, which are driven by motor MG1 by means of suitable gear systems (see fig. 1-14). As already explained, the compass synchro information causes the TRD to rotate to a position that is representative of the actual track angle being flown rather than of the desired track angle.

The main cam moves exactly as the aircraft compass: a positive change in degrees causes the main cam to turn clockwise, and a negative change in degrees causes it to turn counterclockwise. Assuming there is no track error, the main cam is at 0°, as shown. With the cams in ZERO position, microswitch S2 is operated by the *transfer cam*; therefore, relay K1 is deenergized. This connects the cross-track pulses from the cross-track actuator to the center arm of S4 via contacts NO and C of S10 and contacts 14 and 15, 5 and 6 of K1. Switch S4 is driven by the 10-speed cam, which is turning 10 times as fast as the main cam. This, therefore, amplifies any movement of the main cam, and a one-tenth-degree change moves the cam one full degree. This is very important, because it is at this point that the transfer of cross-track pulses must be made from left counter to right counter in the controller, and vice versa. The transfer cam maintains S2 open for approximately ± 13.5°, and relay K1 remains deenergized. The cross-track pulses, therefore, are directed by S4 to either right or left counters.

When the transfer cam, which is on the same shaft as the main cam, turns sufficiently, its roller allows the NC contact of S2 to be connected to ground, which energizes K1. This relay then switches the cross-track pulses from the 10-speed cam switch (S4) over to the main cam switch (S3) via contacts 12 and 13 of K1. When the main cam assembly turns a few more degrees, the butterfly cam connects C and NC of S10. Thus, S10 has taken over the function of contacts 12 and 13 of K1. K1 then is ready to operate with the 10-speed cam at 90°, 180°, or 270°. This insures contact at all times during transfer.

When the track error is in quadrants 1 and 4 of the X and Y coordinates, the along-track pulses are conveyed directly by S5 and S1 to the counters in the controller. When the track error becomes +90°, the transfer cam once again actuates switch S2 and relay K1 is deenergized.

This connects the center arm of S4 to the along-track actuator via NO and NC of S5 and contacts 6 and 5 of K1. Therefore, the 10-speed cam is now operating in the along-track circuit and amplifies any movement at +90°. This action insures great accuracy in transfer.

Similarly, the 10-speed cam is switched in and out of the circuit at 180° and 270°. The butterfly cam switches the 10-speed cam from cross track to along track. Since the 10-speed cam is used four places, it follows that the 10-speed cam action is 180° out of phase (i.e., left motion becomes right, and increase becomes decrease). The antiphase cam, together with switches S6 and S7, reverses these connections to provide the correct sense to the signals. Sections 14 and 15 of K1 prevent the along-track and cross-track outputs being shorted together during transfer by the butterfly cam and S10. Thus, the along-track pulses and the cross-track pulses are switched to the proper counters in the control indicator.

The main camshaft is rotating directly as the compass. By the gear system, this rotation is doubled and drives the sine-cosine potentiometer (R301,

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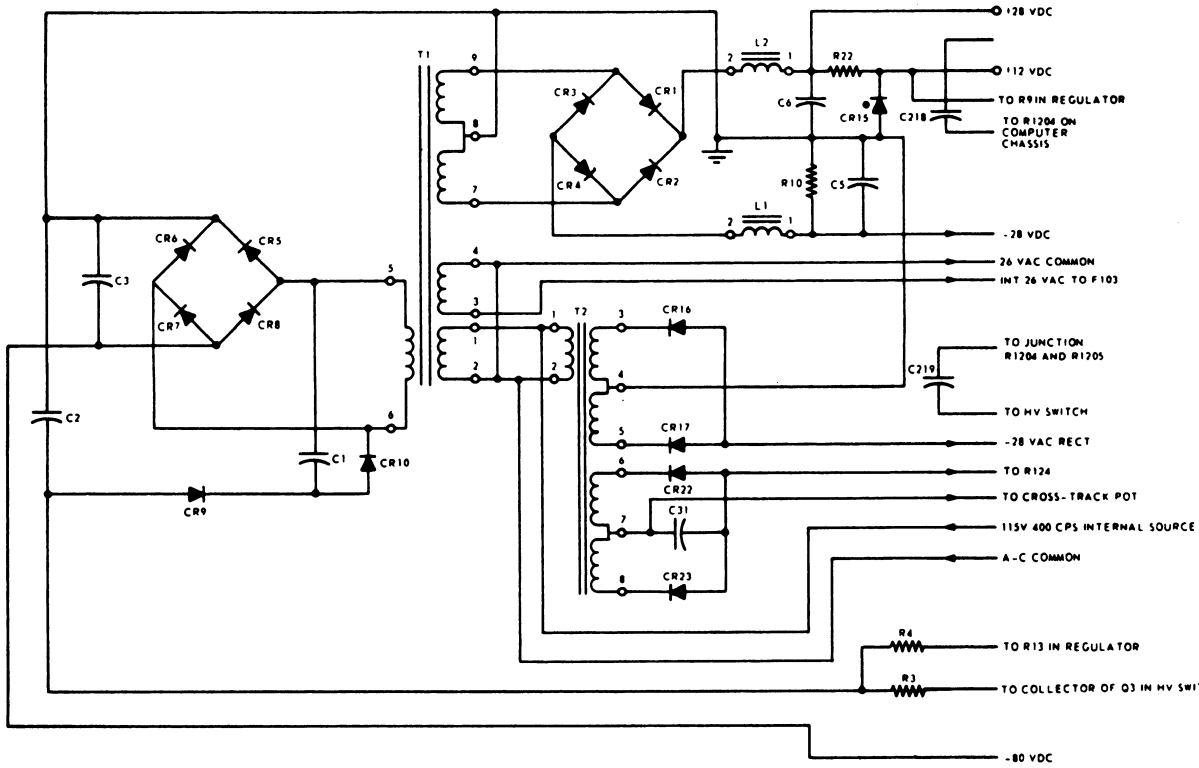

Figure 1-15. Power supply.

fig. 1-6) at twice the compass speed. Further, gear drives cause the 10-speed cam to rotate at 10 times the speed of the compass. MG1 drives the system through a 1:64 stepdown gear. Control transformer CT1, autopilot synchro TX1, and indicator synchro TX2 are coupled 1 to 1 with the main cam and the compass. Diode CR1, across K1 coil, damps any spike voltage which might be generated as K1 opens and closes.

Exercises (A08):

1. What is the purpose of the motor and servoamplifier in the track resolver drive?

2. What is the purpose of the track resolver drive?

3. If an aircraft is flying with a heading in the third quadrant (using X and Y coordinates), what happens to the distance to go and distance cross track?

A09. Explain pertinent requirements of the power supply and regulator circuits.

The Power Supply. The various voltages used in the computer are developed in the power supply. Where regulation is required, a regulator assembly operates in conjunction with power transistors in the power supply to give regulated voltages. Proper operation of the resolver circuit in figure 1-6 requires that the ratio of the -30 volts and the -50 volts DC remain constant, regardless of fluctuations that may occur in either voltage. This is done in the regulator by using the -30 volts DC as a reference voltage for the -50 volts DC regulator circuit.

Refer to figure 1-15. The 1-2 windings (primary) of transformers T1 and T2 are supplied with 115 volts AC, 400 Hertz. Full-wave rectification by CR16 and CR17 in the secondary of T2 produces an unfiltered -28 volts DC. This voltage supplies the along-track and cross-track output transistors with the high current to drive the counter relays. The remaining output of T2 is rectified by CR22 and CR23 and filtered by C31 and R1204 (on the computer; figs. 1-4 and 1-6) to produce 12 volts DC. This voltage supplies the cross-track potentiometers in the control indicator and in the auxiliary cross-track control indicator.

Transformer T1 supplies the voltage to the regulators. One secondary (pins 3 and 4) of T1 develops 26 volts AC. Another secondary of T1 (pins 7 and 9) develops +28 volts and -28 volts DC after rectification

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by diodes CR1 through CR4 (arranged in bridge configuration). Choke L2 and capacitor C6 provide filtering for the +28 volts DC. Choke L1 and capacitor C5 filter the -28 volts DC. Resistor R22 drops the +28 volts DC to provide +12 volts DC. Zener diode CR15 regulates the +12 volts DC. The remaining secondary of T1 feeds a voltage doubler circuit, CR9 and CR10, that produces the -160 volts used in the high-voltage switch. Bridge circuit CR5 to CR8 produces -80 volts DC, which feeds the regulator circuits.

The heat sink consists of two metal chassis on which are mounted four transistors and transformer T3 (fig. 1-13). Since the power dissipation of output transistors Q3 and Q4 in the servoamplifier is high, these transistors, together with their drive transformer (T3), have been mounted on a special metal plate to disperse the heat. Similarly, power transistors Q1 and Q2 in the power supply have been mounted on these same plates.

Regulator Circuit. The regulator, in conjunction with some of the circuits in the power supply, regulates the -80 volts DC from the power supply to produce three output voltages: -30, -31.5 and -50 volts. For the purpose of regulator circuit description, figure 1-16 is a simplified schematic that combines only those parts of the power supply and regulator that are used for regulation.

Diodes CR5, CR6, CR7, and CR8 (in the power supply, fig. 1-15) provide -80 volts DC to the regulator. Regulator transistor Q7 in figure 1-16 controls the regulated -30-volt supply. Diode CR1 provides a -10-volt reference for this regulator. The -30-volt supply, in turn, provides the reference voltage for the -50-volt supply regulator transistor, Q8. The same -50 volts is used as the supply for the first regulator, Q7 and CR1. This results in two voltages having the constant ratio which is important in the resolver circuit. Transistor Q7 controls the base potential of power supply transistor Q2. Capacitor C8 acts as a further filter so that the resultant DC is very smooth and stable. Transistor Q8 uses this regulated -30 volts as a reference and so provides the control voltage to the base of Q1 in the power supply. The collector of Q8 is supplied with a regulated -54 volts from the -160-volt supply by means of R13 and Zener diode CR2. Power supply transistor Q1 is in series with the -80-volt DC supply and so lowers this voltage to -50-volt DC. The -50 volts is further divided by R10 and R11 to provide -31.5 volts to the resolver, where it is used as the basic reference of the NPN multiar.

Should the output of the -30-volt supply increase for any reason, the base voltage of Q7 goes more negative, and since the emitter is held at -10 volts by CR1, Q1 passes more current. This, in turn, causes the collector of Q7 to go more positive. Since the base of Q2 is connected directly to this collector, Q8 passes less current and the output tends to remain at -30 volts. Thus, the initial increase in voltage is reduced

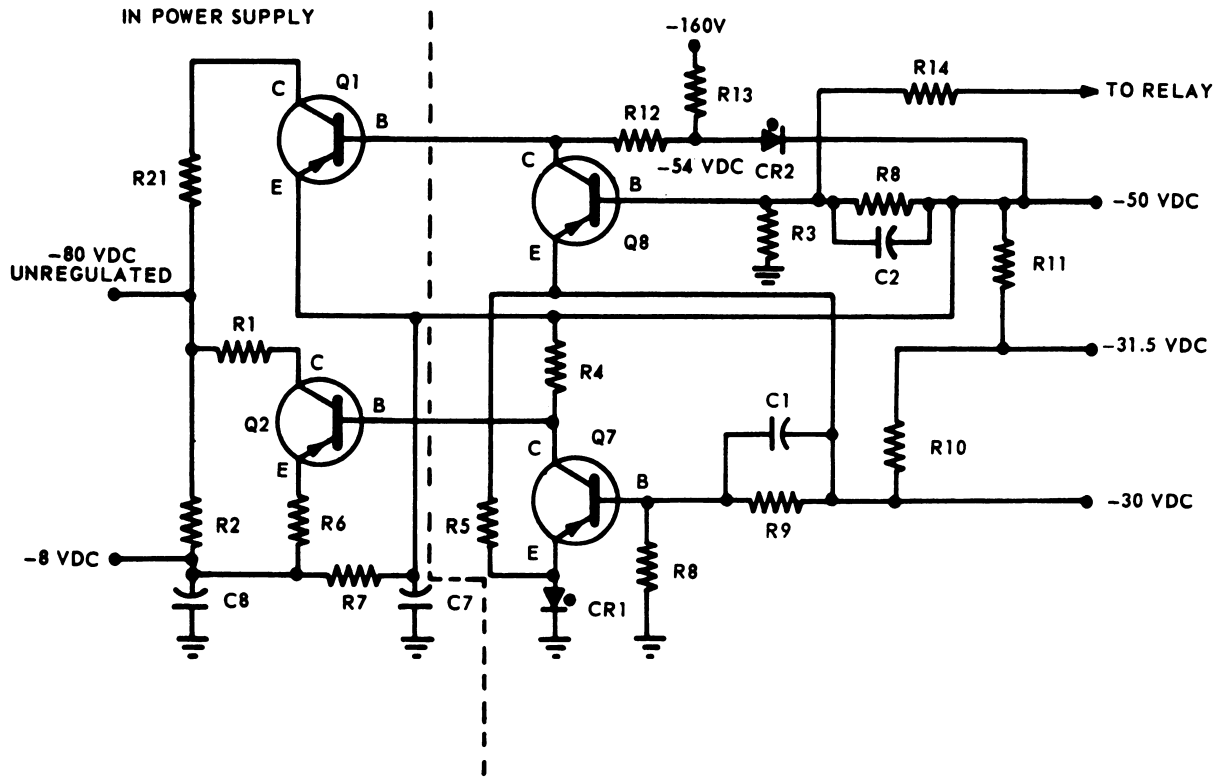

Figure 1-16. Regulator circuit.

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instantly, resulting in a stable supply. Conversely, if the -30 volts tends to decrease, it is stabilized. Since transistor Q8 uses the -30 volts as its reference, any increase or decrease in the -50-volt supply causes its base voltage to change, so the collector of Q8 reflects this voltage fluctuation. In a manner similar to the -30-volt system, transistor Q7 raises or lowers the -50-volt supply to stabilize it at the mean value.

Resistor R14 is grounded through the relay when the Doppler and computer systems are in the SEA STATE. This causes the base of Q8 to go less negative. Q8 interprets this as a decrease in the -50-volt supply and causes Q1 to raise its output, and the -50 volts rises. This causes the overall gate time of the clock multiar to increase by one-half percent, thus changing the computer division ratio. Capacitors C1 and C2 prevent high-frequency oscillations in the power supply. Resistors R2, R6, and R7, and capacitor C7, provide -8-volt DC to diodes CR2 and CR3 in the HV switch. This provides them with the correct current, keeps the power dissipation low, and keeps the regulator current from going to zero. Resistors R1, R6, R7, and R9 in the regulator compose a portion of the resolver bridge.

Exercises (A09):

1. What type of rectification is used in the power supply?
2. What is the purpose of the regulator in the power supply?
3. Why is a heat sink necessary in the power supply?

1-4. The Control Indicator

The control indicator has three major assemblies—the along-track assembly, the desired-track assembly, and the cross-track assembly.

A10. Cite or explain actions concerned with the operation of the control indicator.

Along-Track Assembly. The along-track assembly provides continuous distance-to-go information which is read out on a three-digit counter. See figure 1-17 for a simplified schematic.

Distance-to-go pulses from the computer are fed through active-off stage selector switch S2 (pins 1

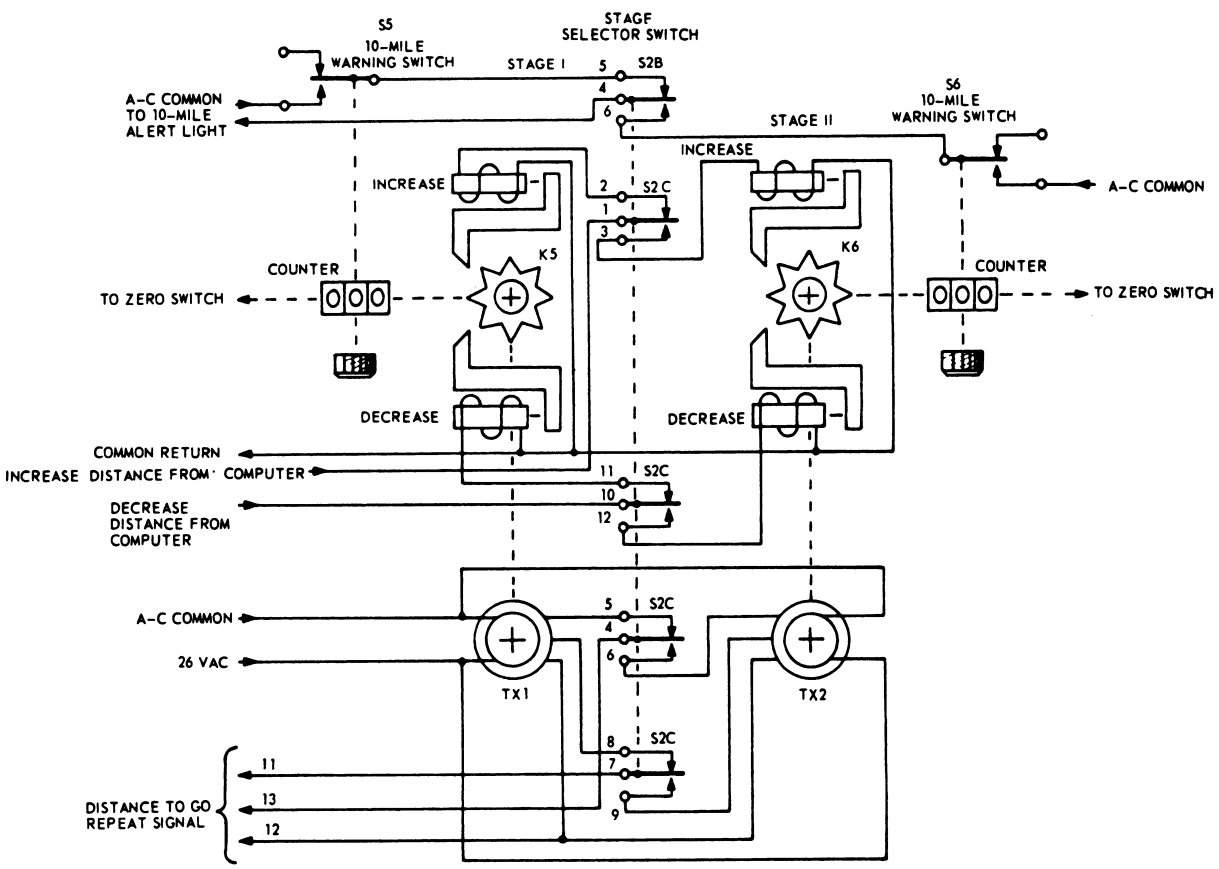

Figure 1-17. Along-track counter assembly simplified schematic diagram.

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and 10) to the counter control relay (K5 for STAGE I and K6 for STAGE II). Each relay coil actuates a panel that drives a star wheel connected to the counter shaft, thus stepping the counter. The computer supplies either increasing or decreasing distance-to-go pulses, depending on the direction of flight. If the distance to go is decreasing, a signal is fed through pins 10 and 11 of S2C to the "decrease" coil of the counter control relay in the active stage. (STAGE I is active, as shown in fig. 1-17.) The panel then drives the star wheel in the direction that decreases the counter reading. Alternately, if the distance to go is increasing, a signal is fed through pin 1 of S2C to the "increase" coil of the counter control relay, and in a similar manner the counter reading increases. The signal return path is common and is fed from either relay coil back to the computer. Synchro transmitters TX1 and TX2 are ganged with the counter shafts and transmit distance-to-go data to the air navigation multiple indicator.

Figure 1-18 shows the circuit as it is when both stages have some miles to go (i.e., the counters in both stages have readings other than zero). When on AUTO (S1 closed), zero switches S3 and S4 cause automatic changeover from STAGE I to STAGE II, or vice versa, when a stage reaches zero miles. It will not switch into an empty stage. The drawing shows both stages with miles to go. In this condition there is no path for current from ground to the +28 volts. Therefore, no current flows. However, as soon as the active stage (STAGE I in this case) reaches zero miles, then pin 1 of ZERO switch S3 switches to the right and makes contact with pin 3. Immediately,

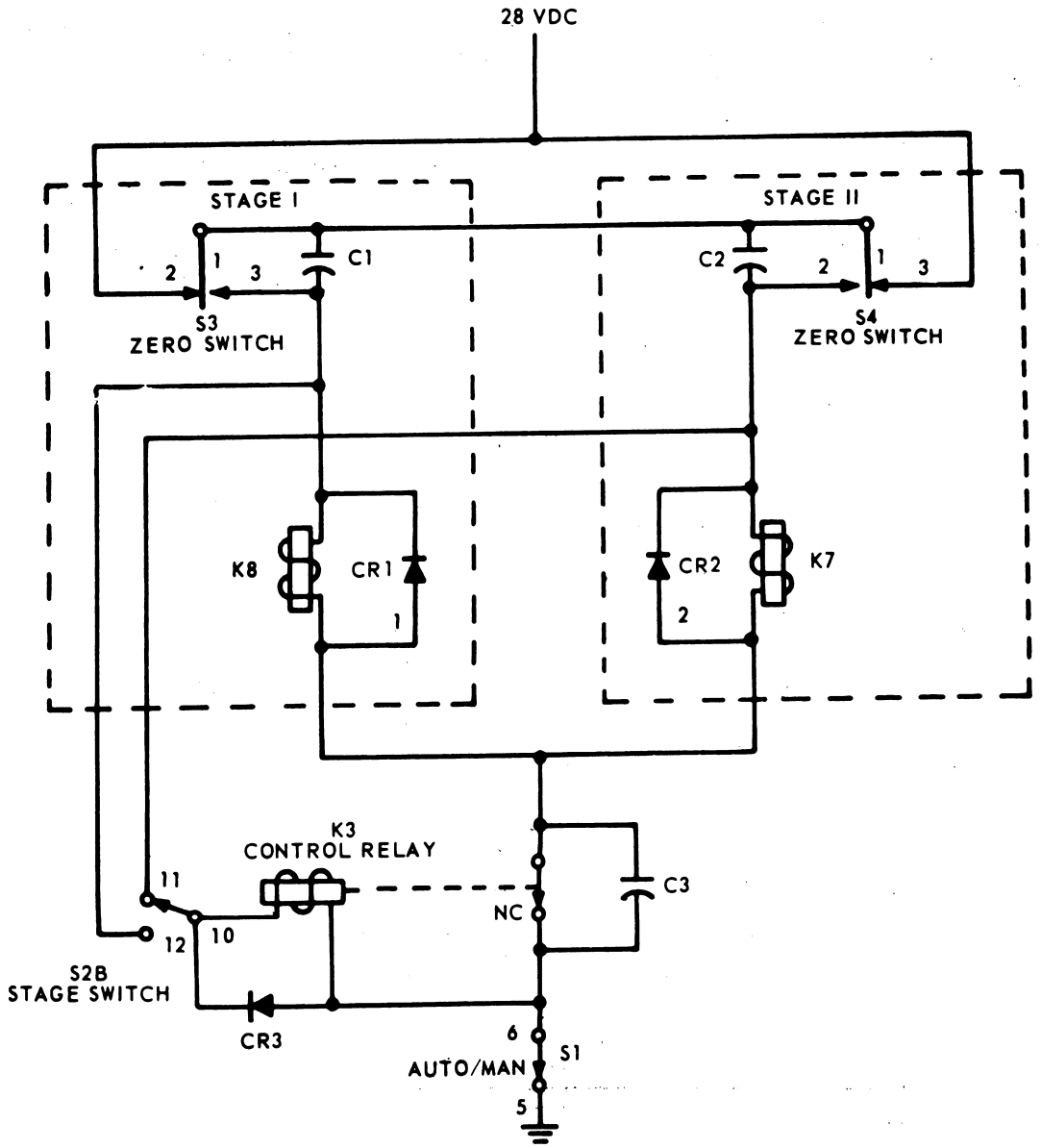

Figure 1-18. Automatic stage switching, simplified schematic diagram.

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the +28-volt path is from ground through S1, the normally closed contact on relay K3, pins 1 and 3 of S3, pins 1 and 3 of S4 to +28 volts. Relay K8 is thus actuated and, by means of an arc gear (not shown), stage switch S2 is driven from the STAGE I position to STAGE II; i.e., arm 10 on the stage switch S2B moves from contact 11 to contact 12. On reaching contact 12, S2B provides the +28 volts DC to relay K3, which opens its NC contact and removes the common ground from both switching motors. As explained previously, the system will not switch into an empty stage, because when either stage is at zero miles, relay K3 remains energized. K3 remains energized until both stages are either at ZERO or both have miles to go. Automatic switching from STAGE II to STAGE I is the same relative procedure. Diodes CR1, CR2, and CR3 dampen any oscillation in the relay coils.

Desired-Track Assembly. The desired-track assembly compares the actual track with the desired track and displays the desired-track information on the STAGE I and STAGE II four-digit track-angle counters. Refer to figure 1-19. Actual track information is supplied to the control indicator from the aircraft compass. Three synchro inputs are fed to the stator terminals of either control differential, CD1 for STAGE I or CD2 for STAGE II, through *stage selector* switch S2A. When the aircraft compass is at 0°, the voltage between S1 and S3 is at a minimum. When the compass rotates in a positive direction, this voltage increases. When desired track CD1 is zeroed, control transformer CT1 in the computer track resolver is also zeroed.

When either *desired-track angle* control (located on the control indicator) is rotated, the corresponding synchro differential (CD1 or CD2) is rotated through a 360:1 gear train. If the *desired-track angle* counter is increased from 0° to 5°, the voltage across R1 and R2 of the synchro differential is decreased accordingly. In effect, the gear train rotates the differential in the opposite direction to that of the control. The synchro differential causes the main cam in the track resolver to rotate in a counterclockwise direction when the counter reading is increased. The *distance cross-track* counter then receives a *left* cross-track pulse and starts counting left, since the aircraft is to the left of the desired track. When the aircraft turns to the desired track set in, the main cam in the track resolver rotates clockwise to eliminate the cross-track error and stop the distance cross-track counter.

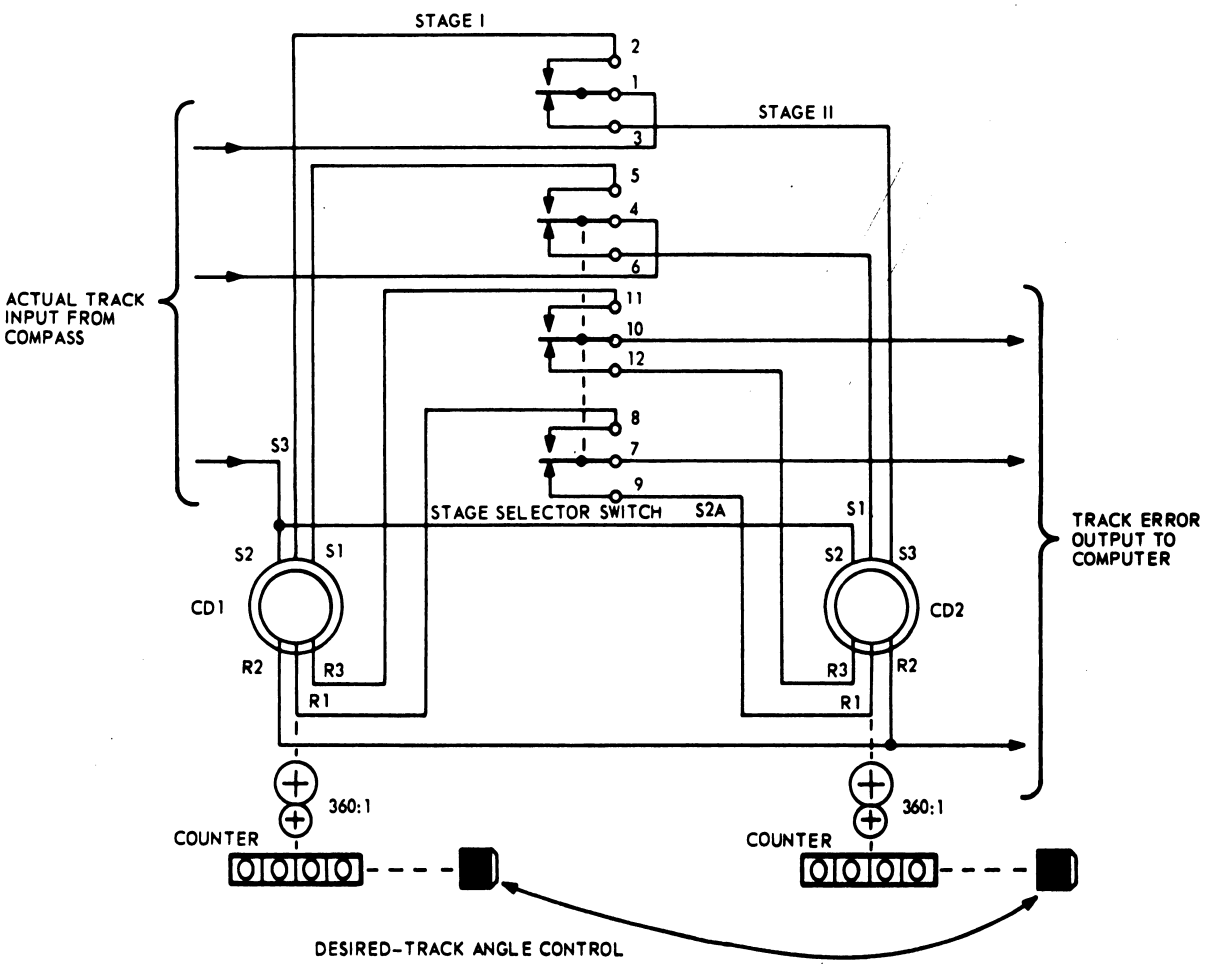

Figure 1-19. Desired track assembly, simplified diagram.

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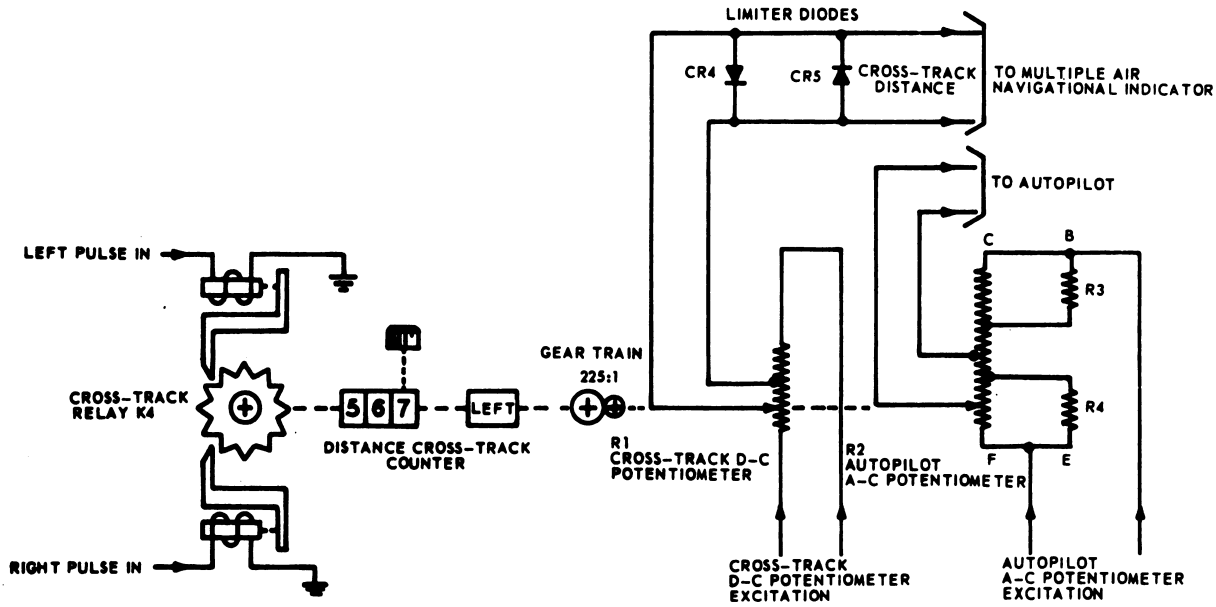

Figure 1-20. Cross-track distance counter, simplified schematic diagram.

Cross-Track Assembly. The cross-track assembly provides cross-track distance information to the left or right of the desired track. The distance is read out on a three-digit counter. (See fig. 1-20.)

The cross-track assembly contains the distance cross-track counter, the cross-track DC potentiometer, and the autopilot AC potentiometer. Cross-track information from the computer is applied to the cross-track counter actuating relay K4. When the *left* pulse is received, the *left* section of K4 is energized and the corresponding ratchet engages the star wheel on the counter assembly. This, in turn, rotates the counter so that the distance cross-track *left* reading is increased or the distance cross-track *right* reading is decreased. When a *right* pulse is received, the *right* section of the relay is energized and the counter reading changes in the opposite direction; i.e., the *left* reading is decreased or the *right* reading is increased.

Potentiometers R1 and R2 provide voltage outputs that are equivalent to the cross-track distance in terms of phase (or polarity) and potential. Potentiometer R1 is mechanically linked to the counter and supplies a DC voltage equivalent to the counter reading to the air navigation multiple indicator and the auxiliary cross-track control indicator. Diodes CR4 and CR5 limit the output voltage to prevent damage to the remote indicators. Potentiometer R2 is also mechanically linked to the counter. Its output, an AC potential proportional to distance to left or right, is fed to the autopilot.

Exercises (A10):

1. What computation takes place in the control indicator?
2. With the AUTO/MAN switch on AUTO, STAGE I active, the STAGE II set to zero miles, how long does it take to switch automatically to STAGE II?
3. What effect does an increase in the desired track-angle counter have on the main cam in the track resolver?
4. What is the purpose of the cross-track assembly?

1-5. Auxiliary Cross-Track Control Indicator

The auxiliary cross-track indicator contains the same cross-track circuitry as does the control indicator, with the addition of three relays—K2, K3, and K4—and two switches, *mode* switch S1 and *distance scale* switch S2. You can see this in figure 1-21. The cross-track indicator circuit is essentially the same as the cross-track circuit in the control indicator described previously.

A11. State operating principles of the auxiliary cross-track control indicator.

Mode switch S1 is a three-position stage selector switch. In the OFF position, the unit is inactive. In STAGE I position, the unit counts distance to right

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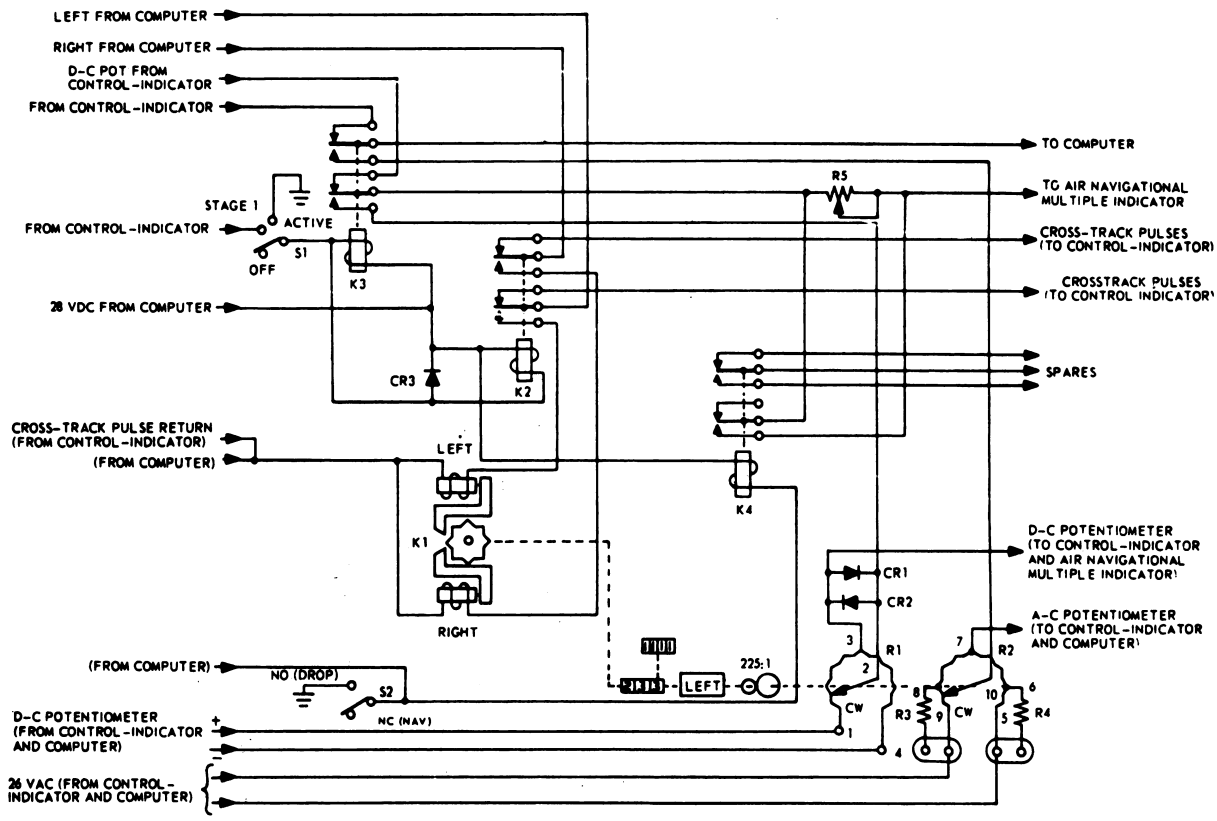

Figure 1-21. Auxiliary cross-track control indicator.

or left of the desired track. Relays K2 and K3 are activated by the *active-off* stage switch in the main control indicator. Thus, when stage transfer occurs from STAGE I to STAGE II, the control is transferred from the auxiliary cross-track control indicator to the cross-track counter of the main control indicator. In the ACTIVE position, relays K2 and K3 are energized continuously, the unit is active, and the main control indicator is inactive.

The distance scale switch, S2, selects a scale of 0 to 99.9 miles when in the NAV position and a scale of 0 to 9.99 miles when in the DROP position. The switch changes the division ratio of the binary channels in the computer by adding or removing the "divide by 10" or "divide by 100" blocks in the sine or cosine channel.

Relay K4 operates when the distance scale switch is in the DROP position. Operation of K4 shorts out potentiometer R5 and increases the sensitivity of the cross-track indicator in the air navigational multiple indicator.

Exercises (A11):

1. With the mode switch of the auxiliary cross-track control indicator in the STAGE I position, which control indicator counts?
2. How does the drop switch change the scale of the cross-track counters?

1-6. Air Navigation Multiple Indicator

The air navigation multiple indicator, shown in figure 1-22, is the pilot's indicator. It displays readings of track-error angle in degrees, distance to go in nautical miles, and the position and heading of the aircraft relative to the desired track. The position and heading of the aircraft relative to the desired-track information are developed in the computer and repeated in this indicator.

A12. State pertinent facts regarding the operation of the air navigation multiple indicator.

Distance-To-Go Circuit. This circuit consists of a control transformer, a magnetic servoamplifier, a 45:1 drive-gear train, a 1:100 gear train, and a three-digit counter. Distance-to-go information from the control indicator is applied to the X, Y, and Z terminals of control transformer CT1. The outputs from the rotor of CT1 are fed to the control windings of

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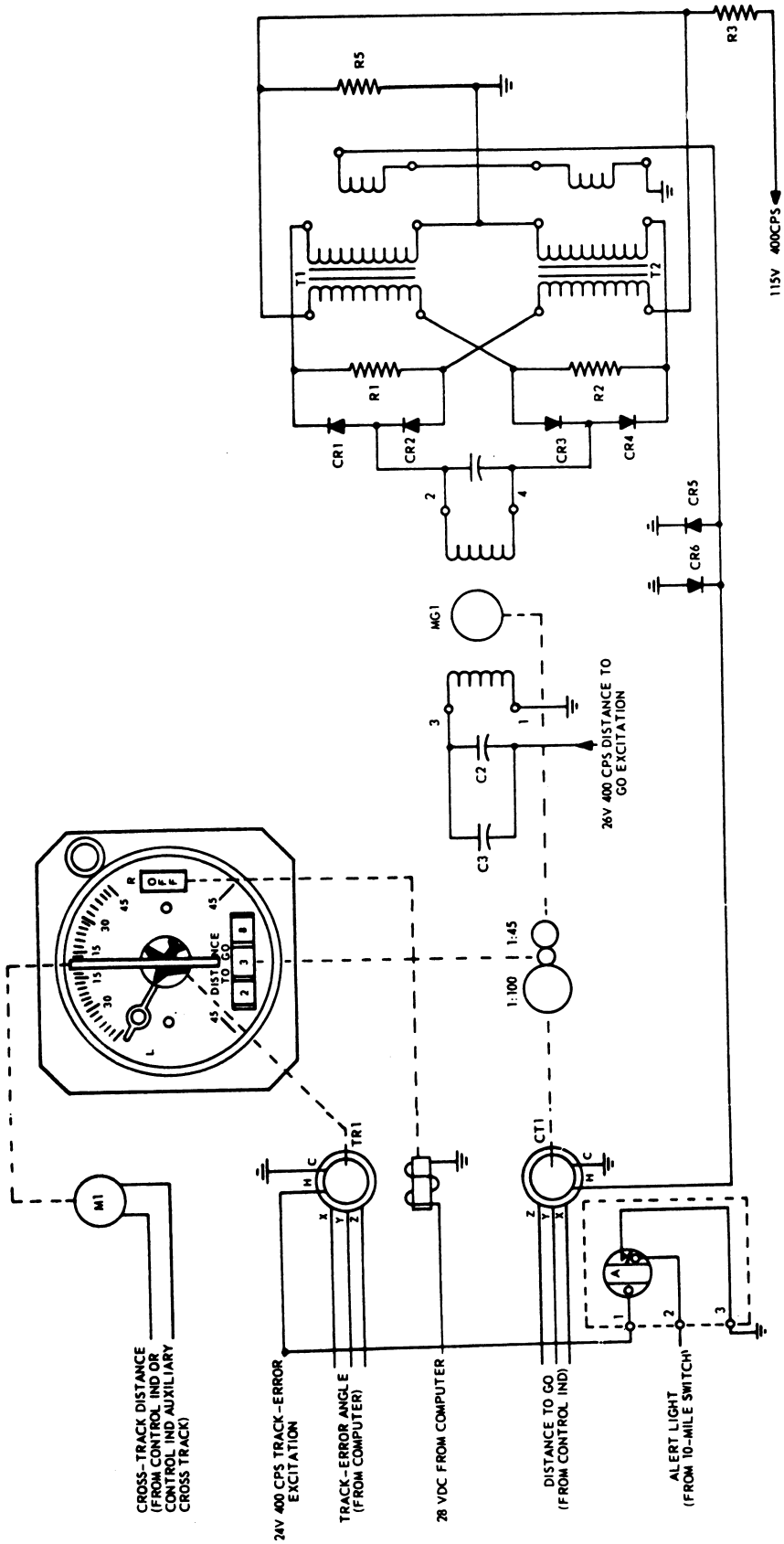

Figure 1-22. Air navigation multiple indicator.

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transformers T1 and T2, which are part of the magnetic amplifier. The output of the magnetic amplifier is connected to pins 2 and 4 of the counter drive motor MG1. When an output is obtained from the rotor of CT1, MG1 drives the distance-to-go counter to the new position through a 45:1 gear train, and a 100:1 gear train rotates CT1 to the ZERO position.

As shown in figure 1-22, the upper left terminal of transformer T1 and the lower left terminal of transformer T2 are common, and 115V, 400 Hertz is fed to both through R3. If there is no change in the distance-to-go information, the output of CT1 is at zero and provides no input to the magnetic amplifier. Since no additional voltage is induced in the secondary windings, the top right of T1 and the lower right of T2 are at the same potential. Consequently, terminals 2 and 4 of the control winding of MG1 are also at the same potential. Therefore, no current flows through the winding and the motor does not run.

When there is a change in the distance to go, the information is fed from the control indicator to the stator of CT1. This produces a rotor output, which is used as an input to the magnetic amplifier. This input affects the magnetic amplifier in such a way as to increase the current flow in T1 and decrease the current flow in T2. The resultant voltage at terminal 2 of MG1 is less positive than during the no-signal, and terminal 4 is more positive. Therefore, there is current flow, and the motor rotates and drives the counter to the new position. The motor continues to drive until the output of CT1 is 0. For the opposite direction, T1 current flow decreases and T2 current increases. This causes current flow from terminal 4 to terminal 2 of MG1, and MG1 rotates in the opposite direction. Diodes CR5 and CR6 limit the voltage from CT1.

Desired-Track Circuit. This circuit consists of meter M1 and a vertical bar to indicate desired track. Cross-track distance information is fed from the control indicator or the auxiliary control indicator to the meter. The meter positions the vertical bar to the left or right of the center of the aircraft pointer.

Track-Error Angle Indicator. This circuit consists of synchro receiver TR1, which controls an aircraft-shaped pointer. The pointer indicates the track-error angle from 45° left to 45° right. Track-error information from the computer is applied to stators X, Y, and Z of TR1. The synchro rotor is mechanically linked to the pointer.

Ten-Mile Warning Light. This light (DS1) indicates when the distance to go is 10 miles from maximum or minimum; i.e., 990 miles or 10 miles. The AC return path for the light circuits is normally open. However, when the 10-mile warning light switch in either counter in the along-track indicator (fig. 1-17) is activated, the path is completed and the lamp lights. The circuit incorporates press-to-test facilities. When the lamp bezel is pressed, the 24-volt AC circuit is completed and the lamp lights.

OFF Warning Flag. The OFF warning flag indicates when the 28-volt DC supply is not available. Normally, 28 volts DC is fed from the computer power supply through the flag-operating relay to ground. When this relay is energized, the OFF flag is held in a position where it is not visible from the front panel. When the 28 volts DC is disconnected, the relay is deenergized, and the OFF flag is positioned in the window.

Exercises (A12):

1. Referring to figure 1-22, if terminals 2 and 4 of MG1 are at the same potential, what happens?

2. DS1 illuminates only when the distance to go is less than 10 miles. True or False.

3. Which control transformer provides signals to the distance-to-go counter drive?

4. What is the purpose of diodes CR5 and CR6?

1-7. Maintenance

This section contains information relative to test and isolate malfunctions of the computer set. Failure of the computer to operate during checkout indicates a malfunction. The malfunction must first be isolated to a faulty component and then to a faulty part.

A13. State the purpose of the checkout procedure.

Checkout. Standardized checkout procedures and tests are used to verify component serviceability. Standard test equipment that you will use are oscilloscopes, audio oscillators, frequency meters, variacs, electronic voltmeters, voltmeters, transistor testers, and galvanometers. Details have already been presented relative to these pieces of test equipment in Volume 2.

Special test equipment that you will use is the computer test harness that provides facilities for bench testing the computer. The computer test harness duplicates the aircraft wiring for interconnection of all the components of the computer set. The heading track simulator in the test harness is used to simulate the heading, track, or track-error angle within 1/10 of a degree. Extension cables and special jigs for servicing the subassemblies are also included in the computer test harness.

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An audio oscillator, utilized with the test harness, is adjusted to either 12,240 or 1224 Hz. This simulates the input from the Doppler sensor. The detailed instructions for a complete checkout are outlined in the applicable technical order and must be followed while performing a system checkout.

Exercises (A13):

1. What is the purpose of the step using an audio oscillator with the computer test harness?

2. What is the purpose of checkout procedures?

A14. Given a hypothetical situation, identify the malfunctioning subassembly or component.

Trouble Analysis. The trouble analysis procedures also require the bench test harness. These procedures help you, the technician, isolate the fault to an LRU. Figure 1-23 is part of a trouble analysis procedure. Note that advantage is taken of test points. The test points are located on front of the test harness and no internal connections are necessary when the harness is installed. Most checks and indications are routine. Each step of the procedure, as shown in figure 1-23, contains test points, test equipment to be used, and instructions followed by logical conclusions. The exercise following this unit provides you with an opportunity to use the TO procedure found in figure 1-23.

Exercise (A14):

1. Refer to figure 1-23. If you were performing step 7 and found the voltage between A4, A5, and A6 does not vary to 10 volts, what is indicated? What action should be taken?

A15. Distinguish between true and false statements concerning TO alignment procedures for the Doppler computer.

Adjustments and Alignments. The Doppler computer is of the analog type and as such incorporates a number of synchros. For proper operation, these synchros must by synchronized or aligned with each other. Figure 1-24 is lifted from the applicable technical order (TO). It illustrates how some of these synchros are to be aligned. Normal procedure is to align all synchros beginning at the first step in the chart and proceeding through each step in sequence. However, let us assume that one synchro has been removed and replaced and that synchro is TX502. Figure 1-24 provides example procedures for alignment of this synchro. Note that the columns identify the procedural steps by number; the test being performed; a reference paragraph; and *in* and *out* test points with the test set, test pin identifier, and signal

Step	Test Point	Test Equipment	Control Settings and Instructions	Normal Indication	If Indication Is Normal	If Indication Is Abnormal
7	Terminals A-4, A-5, and A-6 on computer test harness	Voltmeter AVO-8	As in step 2. Measure voltage between terminals A-4, A-5, and A-6.	Varies between 0 and 26 volts AC.	Air navigation multiple indicator faulty.	Check computer fuses; if satisfactory, proceed to step 8.
8	Terminals B-13 and E-6 on computer test harness	AVO-8	As in step 2. Measure voltage between terminals B-13 and E-6.	26 volts AC.	Control indicator is faulty.	Computer is faulty.
9	Air navigation multiple indicator	Visual	Set STAGE switch to STAGE I ACTIVE. Check that track error angle reads zero degrees.	As detailed.	Proceed to step 12.	Proceed to step 10.
10	Terminals A-7, A-8, and A-9 on the computer test harness	AVO-8	As in step 2. Measure voltages between terminals A-7, A-8, and A-9.	Varies between 0 and 26 volts AC.	Proceed to step 11.	Check computer fuses; if satisfactory, fault is in computer.

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Figure 1-23. Table of computer set trouble analysis.

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Step	Test	Ref Para	In			Out			Remarks
			Test Set	Test Point	Signal In	Test Set	Test Point	Signal Out	
4 (cont)						Voltmeter	E and Y of P501	Approx-imately 32 volts	Rotate TX502 synchro body to obtain maximum reading.
						Oscilloscope	E and D of P501	30 milli-volts	Rotate TX502 synchro body to obtain a minimum reading.
						Voltmeter	C and Y of P501	Approx-imately 32 volts	Rotate TX503 synchro body to obtain a maximum reading.
						Oscilloscope	C and B of P501	30 milli-volts	Rotate TX503 synchro body to obtain a minimum reading.
5	Rota-tion refer-ence for TX501, TX502, and TX503	7-95	Variac	Pins Y and Z of P501	26V ac 400 cps	Voltmeter	Pins F and J of P501	Voltage increase	Rotate shaft of TX501 counterclockwise.
						Voltmeter	E and J of P501	Voltage increase	Rotate shaft of TX501 counterclockwise.
						Voltmeter	C and J of P501	Voltage increase	Rotate shaft of TX503 counterclockwise.

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Figure 1-24. Computer maintenance chart.

characteristics for inputs and outputs to the component under test. Important actions and instructions are provided under Remarks.

You must be careful to perform the actions stated in the Remarks column. For example, note the first remark in the right-hand column in figure 1-24 states that you should "rotate TX502 synchro body to obtain a maximum reading." If you do not rotate the body of the synchro while observing the output, you cannot tell if the output is *peaked to max*. The synchro could, however, produce an acceptable output voltage as specified in the Signal Out column of figure 1-24 (i.e., approximately 32 volts), but be off by several degrees. Thus, the professional maintenance technician will loosen the clamps and rock the body of the synchro according to TO instructions as he observes the output. In this manner, he will obtain the best possible alignment for *max* output. Obviously, we cannot discuss each and every step of the checklist that you use in your work. The performance part of your OJT will provide you with adequate practice with the TO performance checks. You should remember that the checklists are detailed, very practical, and are *required* procedures.

Exercises (A15):

For the following statements, place a T in the blank if the statement is true and an F in the blank if the statement is false.

____ 1. TO checklists are detailed and practical.

____ 2. The TO maintenance chart for aligning the Doppler computer has columns which identify the procedural steps by number; the test being performed; a reference paragraph; and *in* and *out* test points with the test set, test pin identifier, and signal characteristics for inputs and outputs to the component under test.

____ 3. The Doppler computer is of the analog type.

____ 4. The Doppler computer incorporates a number of synchros of which only the even numbered ones must be aligned with each other.

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General Description of Inertial Navigation Computer

THE MAIN FUNCTION of the inertial navigation (INS) computer is to develop a digital readout of the latitude and longitude of the aircraft at any instant, using the outputs of the INS set presented earlier in this course. A secondary function of the INS computer is to compute relative ground-track angle, and bearing and distance from the present position of the aircraft to any chosen destination along the shortest route (the great circle route). Provisions are available for inserting two different destinations as desired. The distance to the destination is given as a digital readout and the magnetic course angle is displayed as a pointer position.

2-1. Description of Components

The INS computer is comprised of three main units—the Computer-Control, the Amplifier Computer, and the Groundspeed Indicator. The following is a brief description of these units.

A16. List the units of the inertial navigation computer and state the purpose of specified controls and indicators of the units.

The Computer-Control. First of the three main units of the INS computer is the Computer-Control, a console-mounted unit containing some of the computing mechanisms of the system. The computing mechanisms are inclosed with a dust-tight cover. The front panel of the unit, as shown in figure 2-1, has seven control knobs for manually inserting information into the system. Associated with each of these knobs is a cyclometer-type counter. The counters visually display magnetic variation, true wind direction, windspeed, present-position latitude and longitude, and target latitude and longitude. A functional selector control (lower left corner of panel) permits selection of any of four modes of operation—TGT–1, TGT–2, STBY, and RESET. An interlock with manual release prevents accidental placement of this switch in the RESET or OFF position. A *set-normal-fix* toggle switch provides manual updating capability. The *variation synch* meter is a nulling device used to update the magnetic *variation* counter. This meter is operative only in the inertial mode of operation (when the Air Data Mode light is out). Located also on the front panel is a Long Range Adj potentiometer control just below the Air Data Mode light. This potentiometer provides adjustment of the long-range computing chain between distances of 120 and 2,000 nautical miles.

The mechanisms in the Computer-Control are electromechanical servos consisting of assemblies of low inertia motors, autosyns, resolvers, mechanical differentials, integrators, and interconnecting gears. These mechanisms are mounted on plates, which are attached to the front casting. The counters, visible through windows in the front casting, are geared to the mechanisms and to control knobs. In this manner, the appropriate autosyns in the mechanism are positioned in coincidence with the setting of the counters. The Position Latitude and Longitude counter control knobs are connected to the gear train mechanism through a shaft lock. The shaft lock is a one-way drive that allows control knobs to position the present-position integrating servo loops without disturbing the position of the servo repeat motors (2B6 and 2B8). This arrangement permits the control knobs to be connected to the present-position latitude (LO_{pp}) and present-position longitude (LO_{pp}) mechanisms when setting in present position of the aircraft and to be disconnected from the mechanism while aircraft present position is being completed during flight.

Amplifier Computer. The Amplifier Computer, second main unit of the INS computer, contains seven servoamplifier modules, one cycle timer, one electronic board, and two servomechanisms. The electronic board consists of filter networks, relays actuated by a precision cyclic timer, and electronic voltage control circuits. The Amplifier Computer also contains a transformer, which provides the 26-volt 400-hertz excitations required by components in both the Amplifier Computer and the Computer-Control. The 115-volt 400-hertz power and the 26-volt 400-hertz synchro excitation power are both applied to the Amplifier Computer. The 26-volt excitation is used in the Computer-Control, whereas the 115-volt power is used both in the Amplifier Computer and in the Computer-Control.

An elapsed time indicator is mounted on the front of the Amplifier Computer to register the length of time power has been applied to the system. Two Deutsch connectors are mounted above the elapsed time indicator. They serve as test jacks to permit simulated compass and true airspeed to be inserted into the system and as test points for flight line or organizational and intermediate level maintenance testing. Two potentiometers are mounted in back of an access cover

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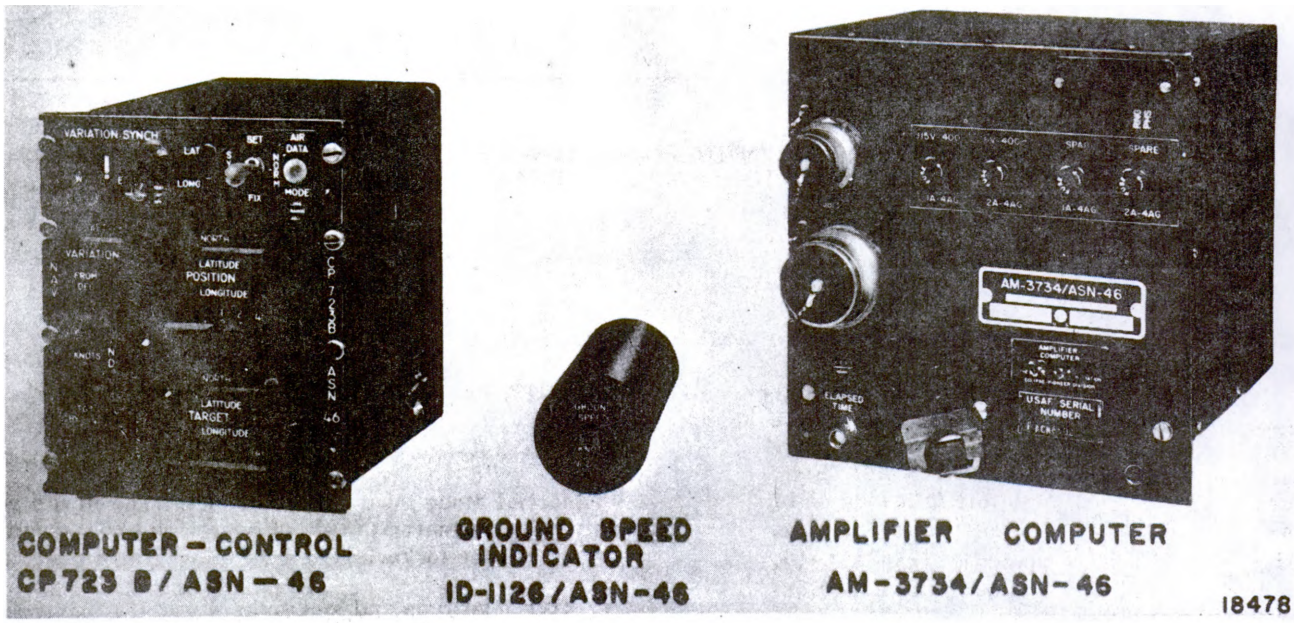

Figure 2–1. Inertial navigation computer set.

just above the fuses. One adjusts range sensitivity, and the other adjusts phase if an Amplifier Computer or Computer-Control is replaced.

Groundspeed Indicator. The Groundspeed Indicator, third main unit of the INS computer, provides a visual display of the aircraft groundspeed. It has a digital readout counter and is capable of indicating between 0 and 1,999 knots.

Exercises (A16):

1. List the major units of the INS computer.

2. What is indicated by the elapsed time indicator?

3. What use is made of the variation synch meter?

2-2. Associated Indicators and Controls

Although the control unit of the INS set and the Computer-Control contain most of the displays for the inertial navigation system, there are other indicators in the aircraft that are very useful to the pilot and navigator. These are the bearing-distance-heading indicator (BDHI) and the horizontal situation indicator (HSI).

A17. Identify the indications for given settings of controls on the BDHI and the HSI.

Computer Presentations on the BDHI. The computer presentations on the BDHI are dependent on the setting of the BDHI mode selector switch on the pilot's instrument panel and on the function switch on the Computer-Control. (The BDHI and BDHI mode selector controls are shown in fig. 2-2). With the BDHI mode selector switch in the NAV COMP position and with the function switch on the Computer-Control TGT–1 position, the BDHI has the following readouts:

- The single bar pointer indicates on the compass card the magnetic bearing to TGT–1.
- The double bar pointer indicates magnetic ground track on the compass card.
- Coincidence of the two pointers indicates that the aircraft is on the great circle route to TGT–1.

The course counter indicates the distance in nautical miles from present position to TGT–1.

With the BDHI mode selector switch in the NAV COMP position and the computer-control function switch in TGT–2 position, the BDHI readouts are the same as above except that they refer to TGT–2.

Computer Presentations on the HSI. The displays on the HSI depend on the setting of two mode selector switches on the mode selector control. (The mode selector control is mounted on the pilot's instrument panel.) The HSI and associated mode selector control are shown in figure 2-3. When the mode switch on the mode

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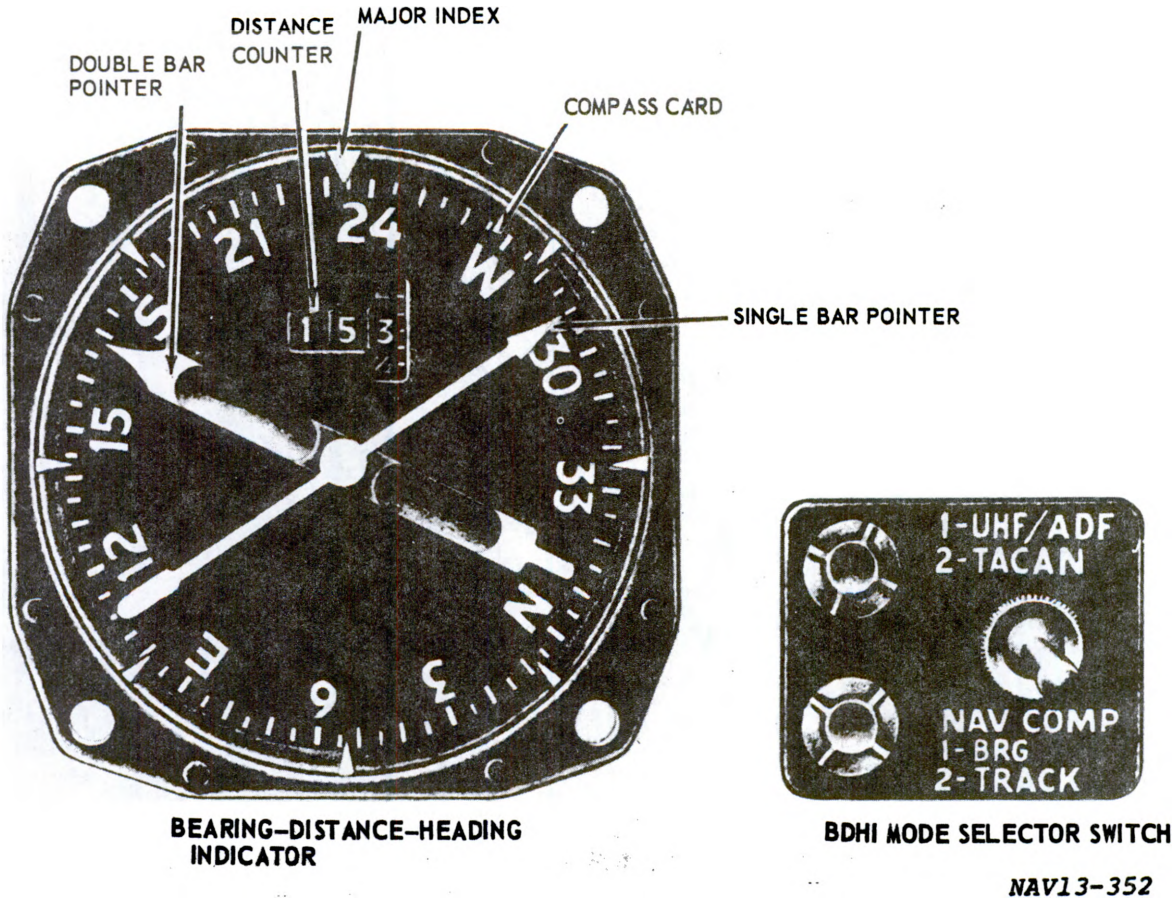

Figure 2–2. BDHI and BDHI mode selector switch.

selector control is set to NAV COMP, the HSI readouts are as follows:

- The course pointer indicates magnetic ground track.
- The command heading marker indicates the heading that must be flown to reach a preselected destination (TGT–1 or TGT–2).

When the BRG/DIST switch on the mode selector control is placed in the NAV COMP position, the HSI readouts are as follows:

- The HSI bearing pointer displays magnetic bearing to the preselected destination (TGT–2 or TGT–1).
- The distance counter displays distance to the preselected destination.

Exercises (A17):

1. Match the settings in column B with the readouts in column A. Items in column B may be used more than once.

Column A	*Column B*
___ (1) Distance counter shows distance to preselected destination.	a. The BDHI mode selector in NAV COMP and the computer-control function switch in TGT–2.
___ (2) Course counter indicates distance in nautical miles from present position to TGT–2.	b. The HSI mode switch and mode selector control set to NAV COMP.
___ (3) HSI bearing pointer displays magnetic bearing to preselected destination.	c. The BRG/DST switch on the mode selector control in NAV COMP.
___ (4) Command heading marker indicates heading that must be flown to reach a preselected destination.	
___ (5) Indicates that aircraft is on the great circle route to TGT–2.	

2-3. Basic Theory of Operation

The navigation computer set has two main modes of operation—the INS mode and the air data mode. The

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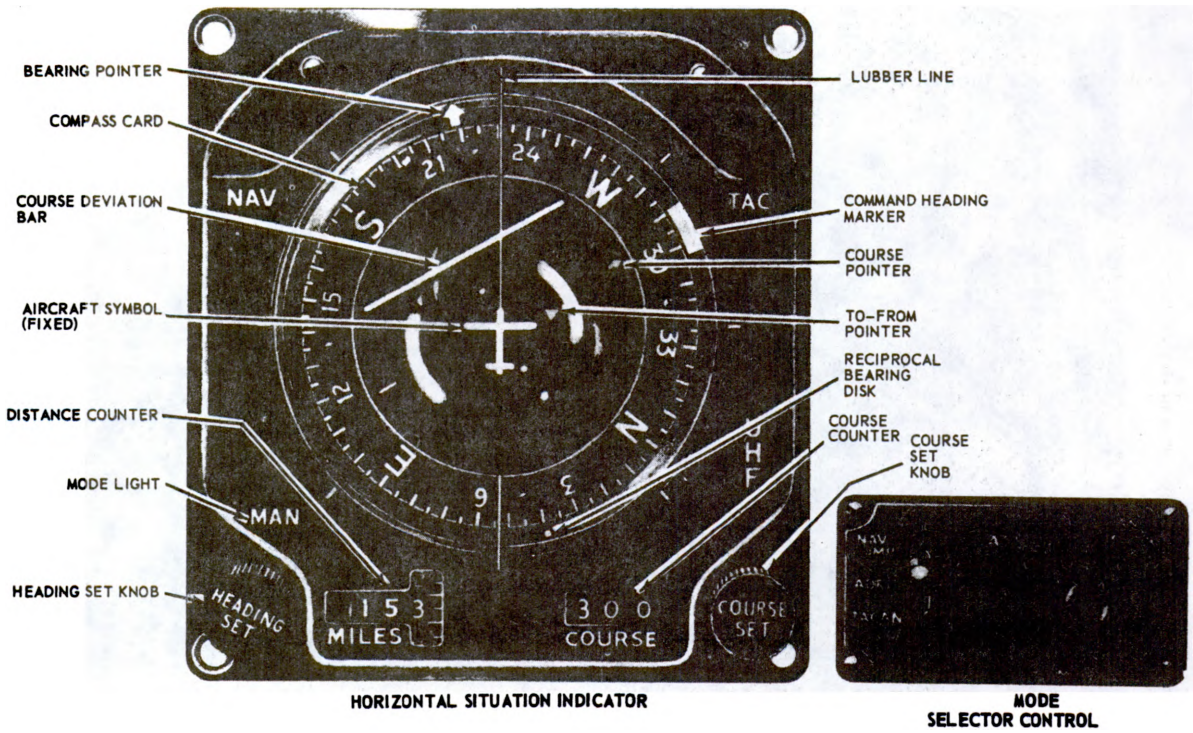

Indicating Device	*Mode Selector Control and Brg/Dist Switch in NAV COMP Position*
Bearing Pointer	Indicates magnetic bearing to destination (base or target).
Distance Counter	Indicates distance to destination (base or target) in nautical miles.
Compass Card	Indicates magnetic heading (read under top of lubber line).
Lubber Line	Fixed reference line on indicator face.
Mode Light	Nav light on.
Course Set Knob	Control has no lasting effect.
Course Counter	Indicates aircraft magnetic ground track.
Course Pointer	Indicates aircraft magnetic ground track.
Course Deviation Bar	Remains centered.
To-From Pointer	Deflected out of view.
Heading Set Knob	Control has no lasting effect.
Command Heading Marker	Indicates magnetic heading to destination (base or target).

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Figure 2-3. HSI and mode selector control.

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difference between the two modes is mainly in the inputs used; the outputs are the same for both modes. Both modes of operation involve dead-reckoning computations. The diagrams associated with these computations are shown in figure 2-4. The symbols used in the computations are defined in table 2-1. Study table 2-1 closely to make sure you know the meaning of these symbols before attempting to follow an analysis of the computer. The inputs and outputs of the computer for both modes of operation are shown in figure 2-5. For either mode of operation, the computer set can be divided into two functional sections—the present-position computer section and the course and distance computer section. We will explain each section with the aid of foldout 2.

A18. State operating requirements and characteristics of the present position computer.

Present-Position Computer. The present-position computer is a group of servomechanisms contained entirely in the Computer-Control, except for amplifiers which drive the servomotors. These amplifiers are located in the amplifier computer.

Air data mode. In the air data mode, the present-position computer receives magnetic heading and true airspeed from associated avionics equipment other than the INS. (See fig. 2-5.) Magnetic variation, windspeed, true wind direction, and present latitude and longitude are set in manually by means of control knobs on the Computer-Control. (See fig. 2-1.) The present-position computer resolves true airspeed and wind velocity into their north-south (N-S) and east-west (E-W) components and adds them to derive aircraft groundspeed. Groundspeed is multiplied by time to obtain distance, which is converted to a change of latitude and longitude. This information continuously repositions the *position latitude and longitude* counters on the Computer-Control in order to display the aircraft's present position. The components of groundspeed and aircraft present-position are also supplied to the course and distance computer (the other computer section).

Magnetic heading and true airspeed signals are derived from a synchro (CX) in the compass adapter compensator and from a potentiometer in the air data computer, respectively (extreme left of FO 2). These signals provide excitation and rotation for the rotor of a true heading resolver (2B14) in the Computer-Control (lower right of FO 2). The magnetic heading must be converted to true heading before true airspeed can be resolved into its true north-south and east-west components. This is accomplished by manually positioning the stator of true magnetic heading control transformer (2B21) to the magnetic variation angle by means of the variation control knob on the Computer-Control. This angle is then algebraically added to the magnetic heading input of the synchro to obtain true heading. This true heading is then applied as a mechanical input to the true heading resolver (2B14) for rotor positioning.

The excitation of true heading resolver rotor 2B14 is obtained from true airspeed potentiometer 2R45B, the rotor of which has been positioned by true airspeed servomotor 2B24. Since the rotor of 2B14 has been positioned with respect to true heading, the resulting rotor output is representative of the north-south and east-west components of true airspeed. These components are added to the corresponding components of wind velocity in the stator windings so that the output of the resolver represents the north-south and east-west components of groundspeed.

The north-south and east-west groundspeed signals from 2B24 are used to (1) continuously update the present-position latitude and longitude counter, (2) continuously update the Groundspeed Indicator, (3) derive a true ground-track signal, and (4) develop a drift-angle signal.

The present-position latitude and longitude counters (extreme left of Amplifier Computer in FO 2) are updated in the following manner: The north-south and east-west groundspeed signals are integrated with respect to time in the corresponding integrator channels to obtain the north-south and east-west nautical miles traveled by the aircraft. The north-south mileage traveled is converted directly into degrees and minutes of latitude by the position latitude counter on the Computer-Control, because 1 nautical mile is always equal to 1 minute of latitude. In the longitude channel, an additional step is necessary because a direct conversion can be made only at the Equator. At other latitudes, the east-west mileage covered is multiplied by the secant of the latitude at which the aircraft is traveling. The actual multiplication is made by an integrator mechanism called the *secant correction multiplier*. The output of the secant correction multiplier is then converted directly to degrees and minutes longitude by the *position longitude* counter on the Computer-Control. During flight, the present-position computer continuously computes the change in latitude and longitude from the aircraft starting position. These coordinate changes are applied to the corresponding position counters, both of which have been manually set before flight to the coordinates of the starting position. Since the position counters add the change in coordinates to the starting coordinates, they provide a continuous indication of the present (current) position of the aircraft during flight.

The Groundspeed Indicator is updated in the following manner: The north-south and east-west groundspeed signals are fed to the stator windings of resolver B801 (top center of FO 4). When this occurs, an error signal proportional to resolver unbalance (rotor not at electrical zero or null) is fed from one coil to the rotor of B801 to the Groundspeed Indicator for counter positioning. The other coil of the rotor of B801 is used as an input signal source corresponding to true groundspeed (Θ_G) for a servoloop consisting of potentiometer R805, servoamplifier A804, and motor B802. Motor B802 positions, simultaneously, the rotors of true ground-track synchro (CX) B812, ground track relative to true heading (drift angle) differential

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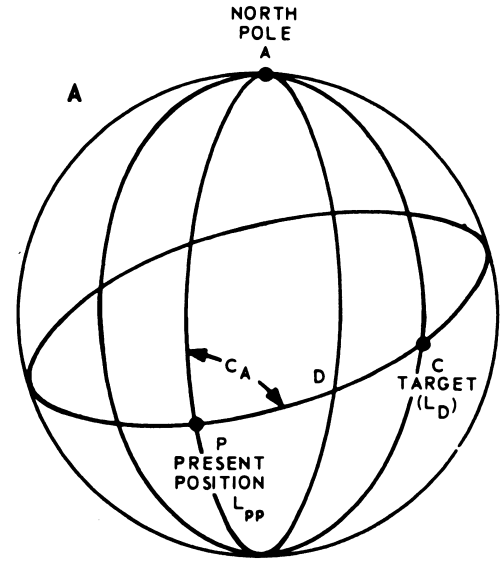
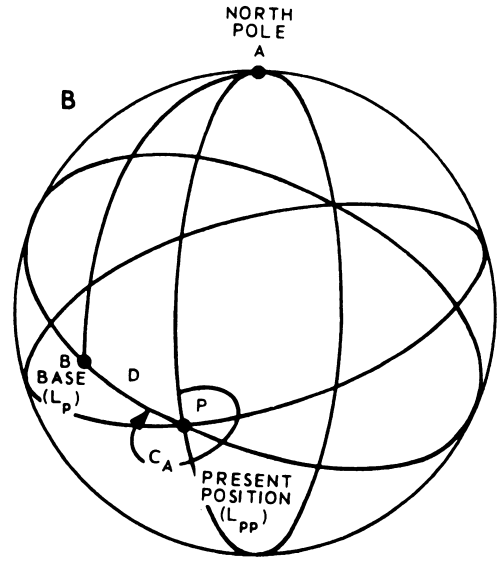
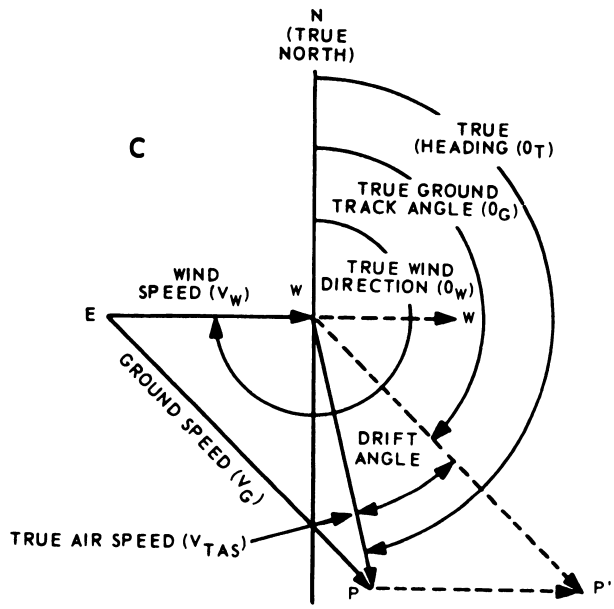


SPHERICAL TRIANGLE FORMED BY THE NORTH POLE, PRESENT POSITION AND TARGET.



SPHERICAL TRIANGLE FORMED BY THE NORTH POLE, PRESENT POSITION AND BASE.



VECTOR DIAGRAM ILLUSTRATING RELATIONSHIP OF THE BASIC DEAD RECKONING TERMS.

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Figure 2–4. Basic dead reckoning and spherical triangle diagram.

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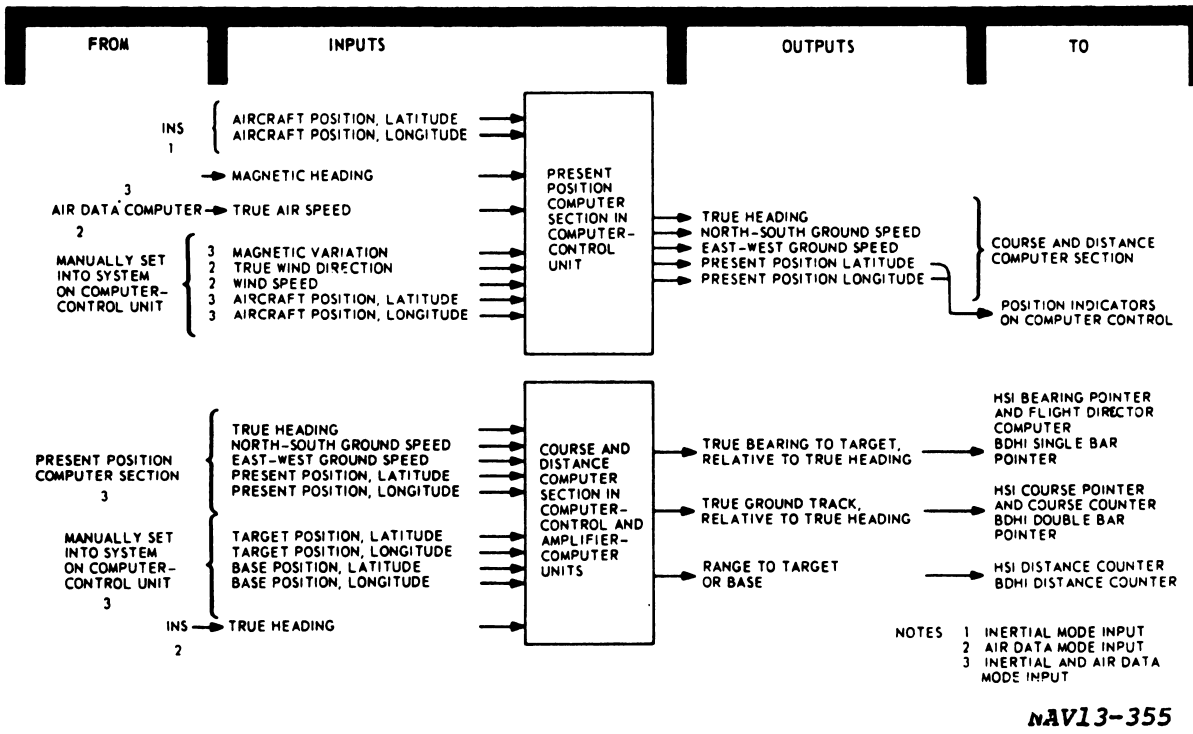

Figure 2–5. Navigation computer set, simplified block diagram.

TABLE 2–1
SYSTEM TERMS AND SYMBOLS

Symbol	Description
LO_{pp}	Present-Position Longitude
ΔLO	Difference in longitude
N-S	North-south
V_G	Aircraft ground speed
V_{TAS}	True air speed
V_W	Wind velocity
Θ_G	True ground-track angle
Θ_M	Magnetic heading
Θ_T	True heading
$\Theta_G - \Theta_T$	Drift angle
Θ_V	Magnetic variation angle
W	True wind direction
Θ_W	Wind direction (from)
C_A	Great circle bearing
D	Great circle distance (range)
E-W	East-west
L	Latitude
L_{T2}	TGT–2 latitude
T_{T1}	TGT–1 latitude
L_{pp}	Present position latitude
ΔL	Difference in latitude
LO	Longitude
LO_{T2}	TGT–2 longitude
LO_{T1}	TGT–1 longitude

transmitter (TDX) B807, and ground-track and groundspeed resolver B801. As motor B802 rotates the rotor of resolver B801 to a new null position, B812 and B807 are correspondingly being updated.

Inertial mode. In the inertial mode, the computer receives the following signals from the INS set: true heading, E-W and N-S groundspeeds, inertial latitude (ΔL), and inertial longitude (ΔLO). During inertial mode operation, ΔL and ΔLO replace the output of the N-S and E-W integrators. Circuits in the INS complete a servoloop with ΔLO input and 2B27 output for servo loop control of the position longitude counter. Another INS circuit completes a servo loop with ΔL input and 2B29 and 2B30 outputs for servo loop control of the *position latitude* counter.

Exercises (A18):

1. Name the manually inserted inputs to the present-position computer.

2. What two signals are combined to obtain true heading?

3. Name all of the inputs that are combined to produce N-S and E-W groundspeeds.

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4. One nautical mile of latitude is equal to how many degrees?

5. In which synchro is ground track combined with true heading to produce drift angle?

6. Name the outputs that depend on servomotor B802.

A19. Identify components of the course and distance computer and define expressions pertinent to its operation.

Course and Distance Computer. The basis of course and distance computation is the solution of a spherical triangle (each side of which is a segment of a great circle) formed on the Earth's surface. One such triangle is formed by the geographic North Pole, the present position of the aircraft, and the preselected target; the other triangle is formed by the geographic North Pole, the present position of the aircraft, and the preselected base. (See fig. 2-4.) The solutions of these triangles are similar since, in both cases, only the present position of the aircraft is a variable, TGT–1 and TGT–2 positions being fixed positions for any one problem.

The latitude and longitude of TGT–1 (usually the starting point) and TGT–2 are manually inserted into the system by means of the *position* and *target* counters on the Computer-Control. Since this information is known within the system, as is the present position of the aircraft, which is available continuously from the present-position computer, two sides and the angle are known. This makes it possible to solve for the third side and the angle, using only the information already available. Referring to figure 2-4,A, the triangle involving the present position and the target, AP is one side, AC is the other, and PAC is the angle between the two sides. Knowing these, it is possible to solve for the third side (PC) and the angle (APC). The third side represents the great circle distance (D), and the angle represents the great circle bearing or course angle (C_A) to the target. Referring to figure 2-4,B, the triangle involving the present position and the base, AP is one side, AB is the other, and PAB is the angle between the two sides. By the same reasoning as above, the third side (PB), distance to the base (D), and the great circle bearing (C_A) to the base can be determined.

When the function selector control on the Computer-Control is placed in the TGT 1 mode, the great circle distance (D) is the great circle distance between the present position of the aircraft and TGT 1, and the great circle bearing (C_A) is the angle defined by the geographic North Pole (true north), the present position, and TGT–1 (fig. 2-4,A). When the function selector control is placed in TGT 2 mode, the great circle distance (D) is the great circle distance between the present-position of the aircraft and TGT 2, and the great circle bearing (C_A) is the angle defined by the geographic North Pole, the present position, and TGT–2 (fig. 2-4,B). In the actual mechanization employed, the solutions are not available simultaneously. The function selector control serves to select the solution desired.

Since the theory of course and distance computation is essentially the same for either TGT–1 or TGT–2 mode, only TGT–1 mode will be discussed at length. In the TGT–1 mode, the rotor of the target latitude resolver (4B18—lower left corner of foldout 2) is positioned manually by means of the target latitude control knob on the Computer Control. Consequently, the outputs of the resolver are proportional to the sine and cosine of the target latitude or sine LT1 and cos LT2.

The longitude difference resolver (LOT - LO_{pp}) is excited by the cos LT1 signal, and the rotor of this resolver is positioned by the output of the mechanical differential. The mechanical differential output represents the angular difference between the target and the present position longitudes. TGT–1 longitude is set in manually before flight by means of TGT–1 *longitude* control knob on the Computer-Control, whereas the present-position longitude is received continuously during flight as an input from the present-position Computer-Control. The outputs of the TGT–1 longitude difference resolver are proportional to cos LT1 cos (LOT1 - LO_{pp}) and cos L_D sin (LOT1 - LO_{pp}). The The former is applied to the present-position latitude resolver and the latter to the bearing resolver. It can be shown that cos LT1 sin (LOT1 - LO_{pp}) is equal to the sine of the great circle distance from the present-position to TGT–1 multiplied by the sine of the angle at the present-position corner of the spherical triangle (fig. 2-4,A). This quantity is expressed as sin D sin C_A, where D is the great circle distance and C_A is the great circle bearing. Thus, the expression "cos LT1 sin LOT1 - LO_{pp}" becomes "sin D sin C_A."

NOTE: The actual mechanization of the Computer-Control includes a series of dummy resolvers in the signal chain (FO 2). These resolvers do not generate any information and, therefore, are not included in the discussion.

In addition to the cos LT1 cos (LOT1 - LO_{pp}) signal, the sin LT1 signal is also applied to the present-position latitude resolver. The rotor of this resolver is positioned by a shaft representing the present-position latitude (L_{pp}). The present-position latitude, like the present-position longitude, is received continuously during flight as an input from the present-position computer section of the Computer-Control. The result is that the output signal from the present-position latitude resolver is proportional to sin D cos C_A, whereas the output signal from the longitude difference resolver (LOT1 - LO_{pp}) is proportional to sin D sin C_A. Both signals are used to excite the windings of the bearing resolver (C_A) included in the Amplifier-Computer. The quantities representing

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these signals define a vector whose length is D and whose direction is C_A.

The bearing resolver furnishes two output signals. One output signal drives the bearing servo so that its output shaft position represents C_A. The second output signal positions the range servo so that its output shaft position represents D. It was mentioned in the previous paragraph that D represents length and C_A represents direction. More specifically, D is the great circle distance between the present position of the aircraft and the target, and C_A is the great circle bearing between the geographic North Pole, the aircraft's present position, and the target. The shaft rotation representing the distance D, in nautical miles, between the present position of the aircraft and the target is applied to a series of geared control transmitter synchros and a switch. These synchros and the switch are geared to each other, in sequence, through 10/1 gear ratios. The synchros thus provide a three-digit distance (range) output where one synchro provides the units figure, the second the tens figure, and the third the hundreds figure. The switch is actuated to provide the thousands figure when the range exceeds 999 nautical miles.

The great circle bearing (C_A), which is the position of the output (rotor) shaft of the bearing resolver, is applied to a torque differential transmitter. The transmitter receives the true heading (Θ_T) from the true heading transmitter and, therefore, its output is $C_A - \Theta_T$, the bearing relative to the true heading or relative bearing. The transmitter supplied this data to equipment external to the dead-reckoning computer set.

In TGT–2 mode, the course and distance computer section of the computer set is the same as that discussed for TGT–1 mode in the previous paragraphs, except that TGT–1 latitude resolver (LT1) is replaced by TGT–2 latitude resolver (LT2), and TGT–1 present-position longitude difference resolver (LOT1 - LO_{pp}) is replaced by TGT–2 present-position longitude difference resolver (Δ LOT2). The two replacing resolvers are required in TGT–2 mode to permit the output synchros to supply the great circle distance and great circle bearing to TGT–2 instead of TGT–1.

In TGT 2 mode, TGT–2 position is the longitude and latitude of the base to which the aircraft is to return at the completion of the mission. This latitude and longitude information must be set into the computer set at the beginning of the flight and then remembered so that it is available when switching to TGT mode. This memory operation is accomplished through the use of the RESET position of the function selector control. In this position of the switch, brakes on the shafts of TGT– latitude resolver (LT2) and longitude difference resolver (Δ LOT2) are released. The LT2 resolver shaft is driven to the present-position latitude by means of LT2 to L_{pp} coincidence mechanism, and the Δ LOT2 resolver is driven to electrical zero, which represents a zero longitude difference, by a Δ LOT2 zero return mechanism (fig. 2-5). Since memory operation is accomplished at the start of the flight, the present position is TGT 2. Therefore, the base references for latitude and longitude have been set into TGT–2 resolvers. When the switch is moved from RESET, the brakes lock the resolver shafts in the reference positions. When the function switch is then moved to TGT 2, the TGT 2 latitude (LT2) and the change in TGT–2 longitude (Δ LOT2) are not available for the course and distance computation.

In the inertial mode of operation, two sets of inertial air data relays provide the means of selecting inertial inputs. These inputs are N-S and E-W components of groundspeed and inertially determined true heading (Θ_T). Once the signals leave the inertial air data relays, they progress through circuitry that is independent of the inertial or air data modes. We mean by this that the theory of operation of the course and distance computer is the same for both the air data mode and the inertial mode.

Exercises (A19):

1. Identify the corners of the spherical triangle that are solved by the inertial navigation computer.

2. Identify the latitude resolver in foldout 2.

3. What does the expression "LOT2 - LO_{pp}" represent?

4. Identify the longitude difference resolver in foldout 2.

5. What do D and C_A represent in the expression "sin D sin C_A"?

6. Identify the bearing resolver in foldout 2.

7. What changes are made in the course and distance computer section when operation is changed from TGT–1 mode to TGT–2 mode?

A20. State the purpose and location of the servoamplifiers and identify the circuits controlled by each amplifier.

Amplifiers. The amplifiers for powering the servomechanisms in the Computer-Control are located in the amplifier computer. Four types of amplifiers are to

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be found in the unit; all of them are transistorized. One type is represented by amplifiers A803 through A806. These are three-stage, single-channel amplifiers used for servoamplification. A second type of amplifier is represented by A802. This is a two-channel servoamplifier. A third type of amplifier—A807A,B,C—serves as a three-channel preamplifier. The fourth type—A808A,B—serves as a two-channel buffer amplifier.

Servoamplifiers A803, A806, and A804 provide the necessary amplification for the range, bearing, and ground-track servos, respectively. Amplifier A805 drives the latitude and longitude integrators alternately, as controlled by a cyclic timer. The switching of the single amplifier between the two integrators does not detract from the integrator performance; thus, it saves space and weight by allowing one amplifier to serve two channels. The control voltage for the A804 ground-track servoamplifier is picked off of potentiometer R805 (upper center of FO 2). The control voltage for the A803 range servoamplifier is preamplified by preamplifier channel A807B and then filtered in a filter network. Another preamplifier channel, A807C, provides preamplification for the true airspeed channel, A802A, of the dual-channel servoamplifier. The output of A802A drives the true airspeed servomechanism in the Computer-Control. Amplifier A802B (top center of FO 2) receives the magnetic heading signal and amplifies it for driving the magnetic heading servomechanism in the Computer-Control.

Exercises (A20):

1. Where are the servoamplifiers for the Computer-Control located?

2. Which circuits are driven by A803 and A806, respectively?

3. The purpose of the servoamplifier is to _____ .

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Detailed Analysis of the Inertial Navigation Computer

IN CHAPTER 2 we presented a general functional description of the inertial navigation computer. In this chapter, we present a detailed analysis of the set. Again, we will consider first the present-position computer section and then the course and distance computer section.

3-1. Present-Position Computer—Air Data Mode

The present-position computer section of the navigational computer set integrates the north-south and east-west vector sums of wind and airspeed with respect to time. The integration produces north-south and east-west vectors, which represent the distance traveled by the aircraft in that time. When the vectors are added to the initial starting position of the aircraft, the result is equivalent to the present position of the aircraft. As we discuss the present-position section in the following paragraphs, refer to foldouts 2, 3, and 4.

A21. Trace the air data mode through the present-position computer and state the purposes of specified components.

Wind Resolution. Windspeed (V_w), in knots, is manually inserted into the system by rotating the *wind-knots* knob on the Computer-Control. The information is displayed on an associated counter. Rotating the knob positions the rotor to potentiometer 2R77. The signal from the wiper of 2R77 excites the rotor winding of resolver 2B13. True wind direction (Θ_w), in degrees, is also manually inserted into the system by rotating the *wind-from* direction knob on the Computer-Control. This knob causes the information to be displayed on an associated counter, and it positions the rotor of resolver 2B13. In this manner, true wind direction (Θ_w) is used to resolve windspeed (V_w) into its north-south and east-west components. These component voltages are taken from the two stator windings of resolver 2B13. This is reasonable, since the output voltage of one stator winding equals the rotor excitation times the sine of the rotor shaft position, and the output voltage of the other stator winding equals the rotor excitation times the cosine of the rotor shaft position.

True Airspeed Resolution. True airspeed input information automatically enters the system from the air data computer in the form of a potentiometer signal. This signal is preamplified in A807C, phase-shifted 40°, amplified in A802A, and used to drive servomotor 2B24. The servomotor positions followup potentiometer 2R45B, which restores the amplifier input signal to a null. A cam corrector in the gear train is adjustable for any nonlinearity in the servoloop. Beyond the cam corrector, the shaft position is exactly proportional to true airspeed. 2R45B provides an output voltage proportional to true airspeed (V_{TAS}).

Magnetic heading input information automatically enters the system from the compass adapter compensator in the form of a synchro signal, and a synchro rotor is positioned in accordance with magnetic heading (Θ_M). This is accomplished as follows: The output voltage from the synchro transmitter in the magnetic compass circuits is transmitted to the followup control transformer synchro 2B21. The output of 2B21 is amplified in A802B, phase-shifted 40° and used to drive servomotor 2B22. The servomotor positions the rotor of followup control transformer synchro 2B21 to null in order to balance the servo loop.

The magnetic heading ($\Theta 6_M$) is converted to true heading Θ_T) by adding to it the variation angle (Θ_v). The *variation* knob on the Computer-Control is used to manually insert the variation angle, which is displayed on an associated counter. The actual addition is performed algebraically by rotating the synchro housing (stator) of 2B21. The true heading mechanical output of 2B22 positions the rotor of true heading control transmitter synchro 2B26. The rotor has excitation voltage applied, resulting in the stator of 2B26 transmitting a magnetically determined true heading signal.

True airspeed information excites the rotor of resolver 2B14 while the rotor shaft is positioned by true heading information. In this manner, true heading (Θ_T) is used to resolve true airspeed (V_{TAS}) into its north-south and east-west components. These component voltages are taken from the two stator windings of 2B14, since the output voltage of one stator winding equals the rotor excitation times the sine of the rotor shaft position, and the output voltage of the other stator winding equals the rotor excitation times the cosine of the rotor shaft position.

Determining Groundspeed Components. As previously stated, the north-south and east-west components of wind velocity and true airspeed must be added vectorially to obtain the north-south and east-west components of groundspeed ($V_G = V_W + V_{TAS}$). These components are obtained by connecting the corresponding outputs of resolvers 2B13 and 2B14 in

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series to attain $V_G \sin \Theta_G$ (the north-south groundspeed). $VV_G \sin \Theta_G$ and $V_G \cos \Theta_G$ are, in turn, applied to the stators of resolver B801, where they are added vectorially to produce true groundspeed.

Converting Groundspeed to Distance Traveled. The north-south and east-west components of groundspeed must be integrated in miles covered (D = Vt). The integration is accomplished in two functionally identical integrator channels, one for north-south and one for east-west travel, which share the same servoamplifier (A805). The system functions on an incremental basis. Thus, if an output shaft is made to advance by steps equally spaced in time, with the magnitude of each step proportional to the velocity at that time, then the total motion of the shaft over a period of time encompassing many steps will be exactly proportional to the distance traveled.

In the computer set, the output voltages derived from the true heading resolver 2B14 and the wind direction resolver 2B13, in series, are used to regulate the size of each integrator step. The cyclic timer is used to provide precisely equal time intervals between steps. Each step is produced by connecting the affected channel as a bridge balancing repeater servo loop. Using the latitude integrator channel as an example, the north-south velocity component from resolver 2B14 is subtracted from the output of the latitude linear potentiometer 2R75 in A1 high impedance preamplifier. Initially, potentiometer 2R75 is held at its electrically zero position by means of a mechanical detent mechanism. Thus, the entire output of resolver 2B14 is transmitted by the A1 high impedance preamplifier to the integrator servoamplifier A–805 in the Amplifier Computer. The output of this amplifier drives the latitude motor 2B6 which, in turn, is connected to potentiometer 2R75 through an electromagnetic clutch 2L5. The servo action pulls potentiometer 2R75 out of its zero detent position by an amount sufficient to cancel the voltage at the input to A1 high impedance preamplifier. When this condition is achieved, the servo loop will come to rest. By virtue of gear train interconnection, this action also advances the latitude counter and all components connected to it by an amount proportional to the voltage input. The phase angle of the voltage, 0° or 180°, determines the direction of motion.

In the next portion of the integration time cycle, potentiometer 2R75 is uncoupled from its drive motor 2B6 and A1 high impedance preamplifier and is driven back to its electrical zero position by the zero return mechanism. At this point, the latitude integrator channel is ready for the next cycle of operation. The cycle described above is repeated at a frequency of 30 cycles per minute, 1 second being allowed for the servo action and 1 second for the return motion. Over a period of time this sequence of operations will produce a ratchetlike response of the servomotor output shaft. If the cycling period is constant, the angular sum of the increments of servomotor shaft movement will be proportional to the north-south distance in nautical miles traveled by the aircraft in the time elapsed since takeoff. This arrangement thus functions as an integration which integrates velocity over a time interval to produce distance.

The cycling period, in effect, periodically couples one channel and uncouples the other. Thus, during the period that the potentiometer 2R75 is uncoupled from servomotor 2B6 in the latitude channel, the longitude integrator potentiometer 2R76 is coupled to servomotor 2B8 in the longitude channel.

Over a period of time the shaft movements of servomotor 2B8 in the longitude channel will be proportional to the east-west distance in nautical miles traveled by the aircraft in that period. Conversely, 2B6 in the latitude channel represents north-south distance traveled. In addition, when aircraft speed is increased, larger east-west and north-south ground signals are applied to the latitude and longitude channels. An increased east-west or north-south groundspeed signal results in a larger increment of servomotor shaft movement in the corresponding channel during each cycle of operation. Reversal of the east-west or north-south component direction reverses signal phase in the corresponding channel; it also reverses the direction of the associated servo shaft.

Exercises (A21):

Refer to foldouts 2, 3, and 4 when necessary.

1. How does the rotation of the wind-knots knob on the Computer-Control affect 2R77?

2. Assuming that the rotor 2B13 has been properly positioned, what information is available from 2B13?

3. What purpose is served by 2R45 in the true airspeed servo loop?

4. What compensation is made for nonlinearity in the true airspeed servo loop?

5. Where and how is magnetic heading converted to true heading?

6. What resolver yields the sine and consine of groundspeed?

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7. Where are the north-south and east-west components of groundspeed added to produce true groundspeed?

8. Name the components that make up the north-south groundspeed integrator circuits.

9. What purpose is served by relay K801?

3-2. Present Position Computer—Inertial Mode

There is no windspeed or true airspeed resolution necessary in the inertial mode. The groundspeed components are given as inertial inputs and do not have to be determined as they are in the air data mode. The groundspeed components are used only as inputs to the Groundspeed Indicator in the inertial mode. The position latitude and longitude counters receive their information from respective servo loops that extend between the navigational computer set and the INS.

A22. Name the components of the present-position computer and state the purpose of specified components.

Present-Position Counter Positioning. With the updating switch in the NORM position and the AIR DATA MODE light extinguished, the position latitude and position longitude counters follow the output signals from the inertial navigation system (INS) minute for minute. Present-position latitude counter positioning is accomplished by the coupling of the coarse (2B30) and the fine (2B29) speed transmitters to the shaft of the latitude counter. The resultant synchro transmitter (2B30, 2B29) output excites corresponding synchro control transformers in the INS. Present-position longitude counter positioning is similarly accomplished by coupling the fine (2B27) speed synchro transmitter to the longitude counter. If the present-position latitude and present-position longitude counters are not in agreement or synchronized with the INS, the synchro control transformers in the inertial navigation system will produce error signals. These error signals drive the synchro control transmitters (2B29, 2B30, 2B27) and their coupled counters to agree or synchronize with the inertial system output shafts. In the case of latitude counter positioning, solid-state switching circuitry in the inertial system selects the error signal from the fine speed synchro 2B29 unless a difference of more than 1/2° is indicated. In this case, the coarse speed synchro transformer output from the inertial system is selected and transmitted to the coarse speed synchro transmitter 2B30 in the Computer-Control. In the case of longitude positioning, only the fine speed synchro is used since the only signal component being transmitted is the change in longitude. The actual longitude is not required or computed in the inertial mode. Since the cyclic solid-state timer and all circuitry associated with distance integration is electrically uncoupled in inertial mode, the servo repeat (followup) action in the Computer-Control is obtained by using the distance integration servo motors 2B6 and 2B8, which are continuously coupled by high-precision gear train to the servoamplifiers and to the synchro transmitters. Thus, the integration amplifier A805 (Amplifier Control) drives the latitude servomotor 2B6 in proportion to the error signal derived from the inertial system.

Since true airspeed is not required in the inertial mode, the true airspeed amplifiers A807C and A802A are electrically reconnected to drive the longitude servomotor 2B8 as directed from the inertial system. The required switching is accomplished by relays (K802, K803, K805, 2K6) energized by the same mode signal that operates the AIR DATA MODE light. The LAT and LONG lights, located on the panel computer-control are actuated by two identical circuits consisting of a preamplifier and a biased trigger. These circuits sense the output of the latitude and longitude servoamplifiers and are adjusted to actuate the lights at an output threshold corresponding to an error of 0.5 minutes in either latitude or longitude. When the threshold is exceeded, the light concerned comes on. Below the threshold, lights stay off. This latitude and longitude sync detector network is contained within the Computer-Control. When the updating switch is in the FIX position, or INS is being aligned, the LAT LONG SYNC lights will stay on until the inertial system is aligned with the Computer-Control within 0.5 minutes of latitude or longitude. At all times while in the inertial mode, the amplifier configuration remains as described.

With the updating switch in the SET position, the followup (servo repeat) links with the inertial system are broken. The position latitude and longitude counters do not move except as they are hand set. The inertial system continues to function normally, however, so that if the update switch is returned to NORM from this position, the counters will resynchronize the inertial outputs and will continue as before. With the updating switch in FIX, the computer set position followups are disabled and the inertial system, through its own circuits, is made to synchronize its latitude with that shown on the Computer Control POSITION LATITUDE counter. The fine speed synchro transformer is synchronized to the fine speed synchro transmitter in the Computer-Control, so that when the updating switch is returned to NORM, operation will start from the coordinates shown on the PRESENT-POSITION counter. This function is used for initial setting of the inertial system and for updating in flight.

Exercises (A22):

1. Name the components that make up the servo loop for present-position longitude counter positioning.

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2. What effect does the secant connector have on positioning the longitude counter while it is operating in the inertial mode?

3. Where in the Computer-Control can one find a voltage analogous to present position longitude?

3-3. Course and Distance Computer—Inertial and Air Data Modes.

The inertial and the air data modes employ essentially the same circuitry. The main difference between the two modes is the source of the N-S and E-W groundspeed signals and the true heading signal.

A23. State the purpose of specified components of the course and distance computer.

The course and distance computer consists basically of two computing chains, one for the long-range (great circle) solution, and the other for the short-range (rhumb line) solution. The long-range computing chain employs two parallel chains (one channel for TGT 1 and the other for TGT2) of buffered resolvers that supply the computer amplifier servo loops with range and bearing inputs. However, the target 1 and target 2 channels are essentially identical. The resolvers are used as function generators and multipliers, while the servo loops convert resolver chain output into bearing resolver shaft displacements which position output synchros for course and distance display. The short-range computing chain produces range and bearing outputs similar to those in the long-range solution. However, because there is very little difference between a plane triangle and a spherical triangle solution at this distance (0 to 120 miles), the required solution for a plane triangle becomes a rhumb-line computation. Rhumb-line instrumentation can be scaled satisfactorily to produce large signals at extremely small ranges that results in improved accuracy, resolution, and minimum terminal error at zero ranges. It then follows that the computing elements for rhumb-line or short-range solutions is a more simplified and direct nature. To this end, the short-range computing chain utilizes high-precision linear potentiometers (2R1, 2R3) to produce accurate range inputs to the computer amplifier. These short-range potentiometers are used for short-range computation because of the larger scale factor obtainable. In TGT2, these potentiometers are shaft positioned by a mechanical detent (zero return mechanism) at their null or mechanical center position.

The changeover from short- to long-range computing is made automatically by the sampling of the north-south and east-west outputs of the course and distance computing chains (at output of isolation amplifiers 2A4) by a short-range detector device. This device stimulates the range solution mode in the computer amplifier. It automatically switches in the long range whenever the outputs of the computing chain indicate a range greater than 120 nautical miles. Above 72° latitude, a cam-actuated switch overrides the short-range detector. Target selection (TGT1 to TGT2) applies to short-range as well as long. In this case the target 1 short range potentiometers 2R2 and 2R4 are permanently connected through a differential between their respective TARGET and POSITION counters. They are only connected electrically when a range of 120 miles or less is detected by a short-range detector. The target 2 short-range program can be inserted only in reset mode. At this time the target 2 potentiometers will provide the same outputs as the target 1 potentiometers. With any other position of the function-selector switch, the two potentiometers are uncoupled from the TARGET counters and coupled instead to reflect change in PRESENT-POSITION only. The desired target position is thus memorized and any change in aircraft position (after initial setting has been made) is reflected as a bearing and range change. When target 2 is to be reset, the clutches 2L1 and 2L2 are energized and the potentiometers 2R1 and 2R3 return to their new set positions.

With the Computer-Control set to TGT1 mode, the course and distance computing chain for a long-range solution originates with the orientated (mechanically positioned) target 1 latitude resolver 2B18 whose rotor is positioned as a function of target latitude (L_{T1}). This resolver rotor is excited with a constant scaled voltage. Since its output voltages are equal to the excitation voltage times the sine and cosine of the rotor shift position, the outputs are proportional, respectively, to the sine of target 1 latitude (sin L_{T1}) and the cosine of the target 1 latitude (cos L_{T1}). The cosine output from the target 1 latitude resolver 2B18 provides rotor excitation for the longitude difference resolver 2B19, whose rotor shaft is positioned by a differential mechanism connected between the present-POSITION LATITUDE and TARGET LONGITUDE counter mechanisms. The rotor angle of 2B19 is thus equivalent in longitude between the present position and the target destination, or the polar angle separating these points ((LO_{T1} - LO_{P1}). The resultant outputs from stator windings of 2B19 are cos L_{T1} cos (LO_{T1} - LO_{PP}) or sin D cos C, and cos L_{T1} sin (LO_{T2} - LO_{PP}), respectively. It can be shown that cos L_{T1} sin (LO_{T1} - LO_{PP}), respectively. It can be shown that cos L_{T1} sin (LO_{T1} - LO_{PP}) is equal to the sine of the great circle distance separating the present position and target multiplied by the sine of the angle at the present-position corner of the triangle. This quality may be expressed as sin D sin C_A where D is the great circle distance and C_A is the great circle bearing. The signal representing the function sin D sin C_A is applied to the input of buffer isolation amplifier 2A4-B, whose output signal drives bearing resolver B803 located in the computer amplifier.

The second output LT_1 cos (LO_{T1} - LO_{PP}) of the longitude difference resolver 2B19 provides one of the inputs to the L_{PP} resolver 2B9, with the other input coming from resolver 2B18. The resultant signal from 2B9 (sin D cos C_A) feeds through amplifier 2A4–A and provides one of the inputs for bearing resolver B803

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located in the computer amplifier. The other input to B803 comes from 2B19. The final solutions for range and bearing are made in a pair of computer amplifier servo loops, which are controlled by the stator outputs of the bearing resolver B803. Final solution computation is the same whether the Computer-Control is in target 1 or 2, or in long- or short-range mode of operation. The total field vector induced a resolver B803 which represents the desired course and distance. One secondary winding provides a signal which, by means of amplifiers A807A and A806 and motor B804 drives itself to null, the true heading angle. The same shaft also positions differential synchro B808 in which true heading is subtracted from the bearing to provide the electrical output of relative bearing required for the BDHI(s).

When the bearing winding of B803 has been properly positioned, its remaining secondary winding has a signal voltage induced that is proportional to the sine of the great circle distance to target destination. This signal is used in a bridge balancing servo loop composed of potentiometer R804, amplifiers A807B and A803, and motor B805. R804 produces an output voltage proportional to the sine of the angle through which it is rotated. This voltage is used to balance the resolver output, sine D, so that the potentiometer shaft position is a direct representation of the great circle distance, D.

In order to maintain symmetry with the course and distance resolver chain, the range sine potentiometer R804 receives its excitation from a locked rotor dummy resolver, B806. This resolver in turn receives its excitation from a common excitation source through an isolation amplifier 2A1–B that has identical characteristics to the isolation amplifiers 2A4, used to excite the bearing resolver, B803.

The range motor, B805, also drives the range output mechanism. This consists of three discontinuous gear mechanisms similar to those used in a cyclometer counter. One synchro transmitter B809 for unit miles is geared directly to the motor B805. The motion of the tens of miles transmitter B810 is further reduced through the first mechanism. The motion of the hundreds transmitter B811 is reduced through the first and second interlinked mechanisms, and the thousand mile switch is actuated through all three specially linked mechanisms in series. The four outputs derived from this arrangement produce a BDHI display identical to that of a mechanically driven cyclometer counter.

Inputs to the ground-track servo B802 represent the north-south and east-west components of groundspeed, both of which are received continuously during flight from the present-position computer section of the Computer-Control. These inputs drive the ground-track servo B802 so that the angular position of its output shaft is always proportional to the true ground-track angle (Θ_G). The ground-track servo is updated in the following manner.

The north-south and east-west groundspeed signals from the present-position computer are fed to the stator windings of ground-track resolver B801. When this occurs, an error signal proportional to resolver unbalance (rotor not at electrical zero, or null) is fed from one coil of the rotor of B801 to the Groundspeed Indicator for counter positioning. The other coil of the rotor of B801 is utilized as an input signal corresponding to true ground track (Θ_G) for a servo loop consisting of potentiometer R805, servoamplifier A804, and servomotor B802. Servo motor B802 positions, simultaneously, the rotors of the ground control track control transmitters (CX) B812, the true ground track relative to true heading differential transmitter (TDX) B807, and the groundtrack and ground speed resolver B801. As the servomotor (B802) rotates the rotor of resolver B801 to a new null position, B812 and B807 are correspondingly being updated. The stator of the true ground track relative to true heading differential transmitter B807 receives true heading, Θ_T, from true heading transmitter (2B26) in the PRESENT-POSITION Computer-Control. Therefore, its output is $\Theta_G - \Theta_T$, or true ground-track relative to true heading. The true ground track control transmitter (B812) and the true ground track relative to true heading differential transmitter (B807) supply ground-track information to equipment external to the navigational computer set.

In the target 2 mode, the course and distance computer section of the computer set is the same as that discussed for the target 1 mode in the preceding paragraphs, except that target 1 latitude resolver B2018 is replaced by target 2 resolver 2B2 and the target 1 resolver 2B19 is replaced by the target 2 resolver 2B1. The use of separate resolvers is required in the target 2 mode to permit the output synchros to supply great circle distance and bearing for target 2 instead of target 1.

Exercises (A23):

1. What does the target latitude resolver do?

2. What does the rotor position of 2B19 represent?

3. What use is made of the sin L_{T1} output of target resolver 2B18?

4. What does resolver B803 do?

3-4. Variation Sync Meter

The variation sync meter is operative only in the inertial mode of operation. The variation sync meter, and its associated circuitry, is in the computer-control unit except as noted in the following paragraphs.

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A24. State the purpose and a pertinent operating procedure of the variation sync meter.

Magnetic heading from the compass adapter compensator is impressed on the stator of CT 2B21. The stator of CT 2B21 is mechanically positioned by the magnetic variation control knob, which also positions the magnetic variation counter. The rotor electrical output of CT 2B21 is passed through a phase shift and amplifier circuit in the Amplifier Computer and back to computer-control motor 2B22. Mechanical linkage between 2B22 and 2B21 completes the servo loop, allowing 2B21 to reach a null. The rotor mechanical position of CT 2B21 now represents magnetic heading plus magnetic variation, or true heading. It must be noted, however, that this true heading is accurate only if the correct variation was manually set by the variation control knob. This true heading mechanical position is passed on to the rotor of TX 2B26, which has a 26-VAC excitation on the rotor. The stator of TX 2B26 transmits the true heading signal to the true heading followup control transformer in the INS. The rotor of the INS true heading CT is mechanically positioned to a true heading reference as determined by the gyrostabilized platform. This causes the rotor electrical output to be the difference between the inertial platform true heading and the computer-control true heading. This difference, if any, results from an incorrect magnetic variation, which was set manually into the Computer-Control. This difference signal is sent to a discriminator circuit and to the variation sync meter. The bar on the variation sync meter deflects either right or left, depending upon the polarity and magnitude of the discriminator circuit output. When the variation control knob is rotated so that the variation sync bar centers, the true heading output of Computer-Control CT 2B21 is the same as the inertial platform true heading. This, of course, indicates that the correct variation has been set by the variation control knob and hence is indicated on the variation readout counter as east or west magnetic variation.

The only purpose of the variation sync meter is to allow the radar pilot to continuously update the magnetic variation as manually set by the variation control knob. This is accomplished during inertial mode operation by keeping the variation sync meter bar centered. A correct magnetic variation setting causes the rotor shaft input and the stator electrical output of TX 2B26 to be an accurate analog of true heading. This is necessary because, although the true heading signal required by other navigational computer set components is supplied by the inertial platform during inertial mode operation, the true heading signal is supplied by TX 2B26 during air data mode operation. This true heading source selection is accomplished by relay switching within the navigational computer set. Thus, in the event the system drops out of inertial mode and goes into air data mode, TX 2B26 is ready with an accurate true heading output. However, to be assured of an accurate true heading, the magnetic variation manual input must be updated when necessary by the radar pilot by resorting to maps or other sources depicting magnetic variation.

Exercises (A24):

1. What is the purpose of the variation sync meter?

2. What is the procedure for centering the pointer of the variation sync meter?

3-5. Maintenance

Testing, troubleshooting, and maintenance of the navigation computer are accomplished in much the same way that they are for other equipment presented in this course.

A25. Given a specific theoretical equipment condition discovered during the checkout procedure for the inertial navigation computer, determine the required maintenance action.

System Checkout. The test set used to test and troubleshoot the navigation computer is the control indicator shown in figure 3-1. To check out the operation of the computer with this test set, it is necessary to connect the component units of the computer to appropriate jacks on the front panel of the test set and then follow the procedures outlined in the technical order for the computer.

As in the case with other equipment we have been studying, it is very advantageous to have the components of a working inertial navigation computer permanently connected in a bench check system with the control indicator. When a component unit is suspected of malfunctioning, its operation may easily be checked by substituting this unit in place of the good unit on the bench test setup.

Before performing a system checkout, you must make the preliminary settings on the test set and perform continuity checks on the Computer-Control and Amplifier Computer. If these procedures are not completed prior to the checkout, you may have more trouble making the checks. (Fig. 3-2 is an example of one test in the checkout.)

Exercises (A25):

1. Referring to figure 3-2, and after-setting the computer control VARIATION to 60° E, the BDHI 1 needle reads 300° 30′. What action should be taken?

A26. Distinguish between true and false statements relative to alignment procedures of the computer system.

Alignment and Adjustments. Some of the adjustments performed on the computer system do not

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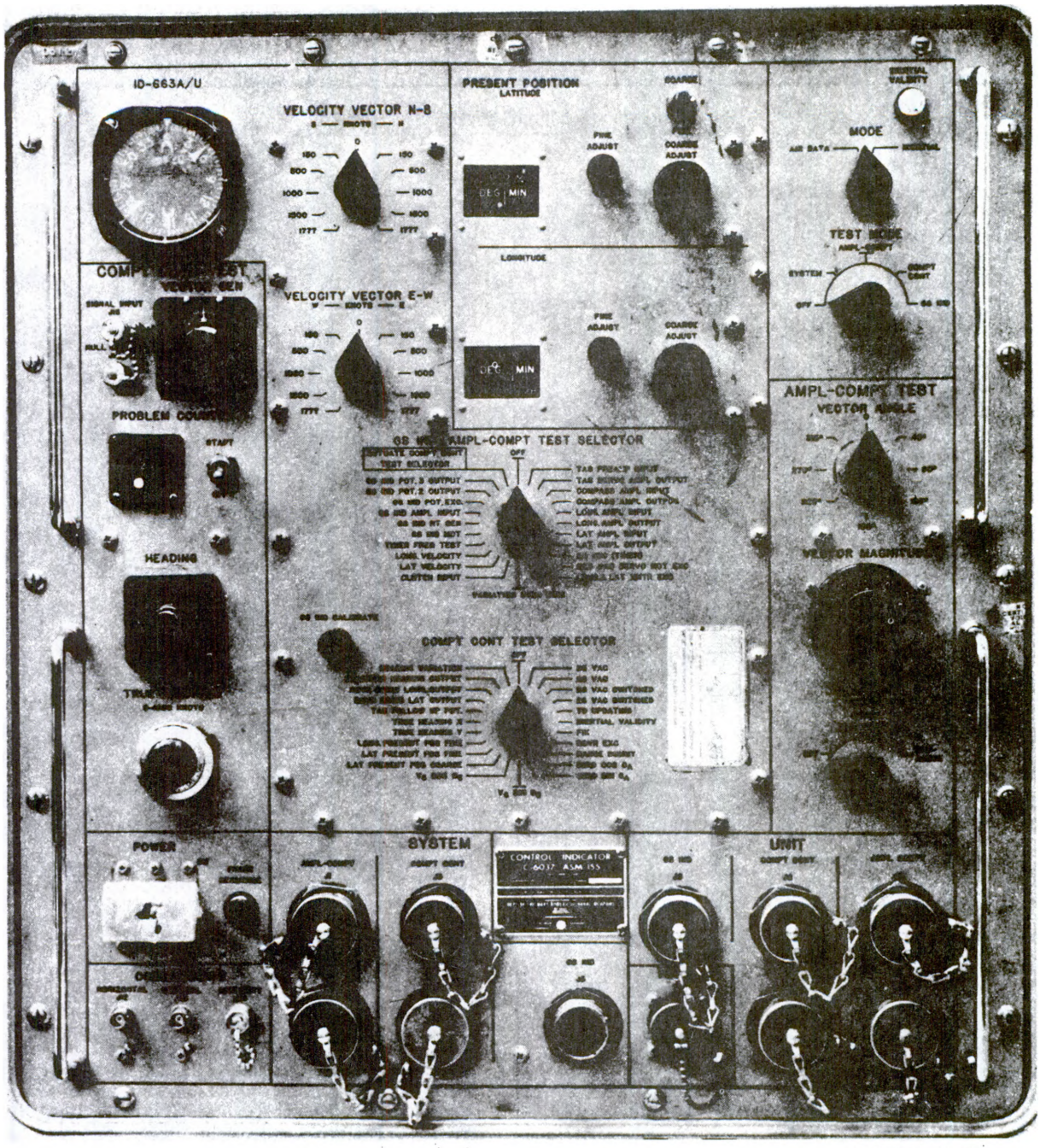

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Figure 3–1. Control indicator.

utilize the standard meters and scope displays. Instead, you perform them while observing indicators such as the BDHI. An excerpt from the TO follows:

7-17. LONG RANGE LONGITUDE AND LATITUDE TRIM ADJUSTMENTS.

a. Make the Bench Test Setup preliminary settings. Remove computer control cover assembly.

b. Place Test Set POWER to the ON position.

c. Set Computer Control Function Selector Control to RESET position.

d. Set compuer Control TARGET LATITUDE to 16°00′ NORTH of POSITION LATITUDE.

e. Set Computer Control Function Selector Control to TGT–1 position.

f. Adjust LONG RANGE ADJ (2R5) located on face of Computer Control to obtain a BDHI range indication of 960 ± 15 miles.

g. Adjust A6R13 to obtain a BDHI range indication of approximately 960 miles and note range indication.

h. Set Computer Control Function Selector Control to TGT2 position.

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STEP NO.	PROCEDURE	NORMAL INDICATION
	AIR DATA MAGNETIC VARIATION CHECK	
5		
a.	Set Computer Control as follows:	
	POSITION LATITUDE NORTH 45°00'	
	POSITION LONGITUDE 00°00' E	
	TARGET LATITUDE NORTH 46°00'	
	TARGET LONGITUDE 00°00' E	
	Function Selector TARGET	
b.	Set Test Set controls as follows:	
	TRUE AIRSPEED 500 Knots	BDHI No 1 and No 2 needles should be at 0 ± 1 degree
	POWER ON	
c.	SET Computer Control VARIATION control as follows:	BDHI No 1 needle should read as follows:
	60°E	300° ± 1°
	120°E	240° ± 1°
	180°E	180° ± 1°
	60°W	60° ± 1°
	120°W	120° ± 1°
	180°W	180° ± 1°
	0°	0° ± 1°
		NOTE If the above normal indications cannot be obtained refer to paragraphs 6-24 and 6-25. If normal indications cannot be obtained after completion of these adjustments then B2021, Magnetic Heading Synchro is defective or broken wires exist.

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Figure 3–2. Air data magnetic navigation procedure.

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i. Adjust A6R15 to obtain a BDHI range indication of approximately 960 miles and note range indication.

j. Set Computer Control Function Selector Control to RESET position.

k. Set Computer Control TARGET LATITUDE to 16°00′ SOUTH of POSITION LATITUDE.

l. Set Computer Control Function Selector Control to TGT2 position and note range indication.

m. Set Computer Control Function Selector Control to TGT1 position and note range indication.

n. Compute TGT1 range difference between paragraph *g* and *m*; by 2; add or subtract this amount as necessary until paragraph*g* and *m* are equal miles value.

o. Adjust A6R11 to the value determined in paragraph *n*.

p. Compute TGT2 range difference between paragraph *i* and *l;* divide by 2; add or subtract this amount as necessary until paragraph *i* and *l* are equal miles value.

q. Set Computer Control Function Selector Control to TGT2 position and adjust A6R17 to the value determined in paragraph *p*.

r. Repeat paragraphs *c* through *e* and *g* through *q* using new ranges to assure an equal range indication on TGT1 between paragraphs *g* and *m;* and TGT2 between paragraphs *i* and *l* with TARGET LATITUDEs both NORTH and SOUTH of POSITION LATITUDE. If range indications cannot be made equal and within tolerance with the above procedure, perform paragraph 7–23, TARGET LATITUDE ZERO ADJUSTMENT.

NOTE

During this recheck only, record BDHI range indication in paragraphs *g* and *i*. No further adjustments are required on A6R11, A6R13, A6R15 and A6R17 potentiometers unless range indications are not equal.

s. Set computer Control Function Selector Control to RESET position.

t. Return Computer Control TARGET LATITUDE to POSITION LATITUDE and set POSITION LONGITUDE 15°00′ E of TARGET LONGITUDE if NORTH 10°00′ LATITUDE is used or to 20°00′ of TARGET LONGITUDE if NORTH 40°00′ LATITUDE is used.

u. Set Computer Control Function Selector Control to TGT1 position.

v. Adjust A7R16 to obtain a range indication of 886 ± 15 miles if NORTH 10°00 LATITUDE is used or a range indication of 917 ± 15 miles if NORTH 40°00′ LATITUDE is used. Record the range indication.

w. Set Computer Control Function Selector Control to TGT2 position.

x. Adjust A7R18 to obtain a range indication as indicated in paragraph *v*. Record the range indication.

y. Set computer Control POSITION LONGITUDE to 15°00′ W of TARGET LONGITUDE if NORTH 10°00′ LATITUDE is used or to 20°00′ W of TARGET LONGITUDE if NORTH 40°00′ LATITUDE is used.

z. Record Computer Control TGT2 range indication.

aa. Set Computer Control Function Selector Control to TGT1 position and note range.

ab. Compute TGT1 range difference between paragraph v and aa.

ac. Slightly readjust A7R16 to obtain a range indication of 886 ± 15 miles if NORTH 10°00′ LATITUDE is used or 917 ± 15 miles if NORTH 40°00′ LATITUDE is used, plus one-half the difference obtained in *ab*.

ad. Compute TGT2 range difference between paragraph *x* and *z*.

ae. Slightly readjust A7R18 to obtain a range indication of 886 ± 15 miles if NORTH 10°00′ LATITUDE is used or 917 ± 15 miles if NORTH 40°00\(fm LATITUDE is used, plus one-half the difference obtained in paragraph *ad*.

af. Repeat paragraphs *t* through *ae* to assure an accurate TGT1 and TGT2 range balance between POSITION LONGITUDE EAST and WEST of TARGET LONGITUDE.

This averaging of the two extremes is also used in many of the other adjustments.

If it becomes necessary to remove the computer control cover, several precautions are in order. First, remove the cover only in an area where temperature, humidity, and dust are carefully controlled. Second, use adjustment tools with care, and avoid contact with exposed electrical terminals.

In the technical order there is a caution: *To prevent damage to the computer-control, replacement and calibration* procedures must be performed only by trained personnel familiar with the navigational computer set. In other words, do not start adjusting synchros unless you absolutely know what reaction to look for. This is no place to experiment.

Exercises (A26):

1. While adjusting the navigational computer, you view all indications on either the VTVM or an oscilloscope. True or false.

2. Only qualified personnel should perform maintenance on the navigational computer set. True or false.

3. The dust cover of the computer control may be removed on the flight line for minor adjustments. True or false.

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CHAPTER 4

Weapons Release Computer System

WE HAVE ALL SEEN antiquated movies showing the first attempts at aerial bombing where the pilot or gunner simply leaned over the side of the canvas-covered plane and released a hand grenade or bomb when he was approximately over the target. Since those early attempts until now, the science of bombing has become more elaborate and sophisticated. No longer does the pilot release the weapon by hand, but precise sighting and release mechanisms have been developed to assist him in obtaining pinpoint accuracy.

In this section, we will discuss the weapons release computer set (WRCS). In order to bomb a target effectively, the bomb must be released at a precise time. This time depends on many variables, a few of which are the altitude, airspeed, and pitch of the aircraft as well as characteristics of the bomb and the delay time of the rack. The WRCS is designed to take all of these factors into consideration when computing the release time. Now, let us see how the computer operates in each of its modes.

4-1. General Description

The weapons release computer set is an analog computer that has six modes of operation. In each of these modes, it provides certain information necessary for the proper release of a bomb or the launch of the AGM–45 missile. Three of these modes are used with retarded-type bombs, one with low-drag bombs, one for short-term navigation, and one with the AGM–45 missile. In each case, except target-find mode, the WRCS computes the proper release time and conditions and develops the release signal. Some modes use the lead computing optical sight system (LCOSS), some the radar, and others a combination of both.

In the laydown, dive laydown, dive toss, and offset bomb modes, the computer provides range information and generates a bomb release signal. It provides range-to-target and steering information in the target find and offset bomb mode. In the AGM–45 mode, the WRCS provides maneuver signals and a missile release signal.

A built-in test (BIT) can be performed on each operational mode and a go or no-go light indicates system status.

A27. State the purpose and identify characteristics of the six operational modes of weapons release computer sets.

Weapons Release Computer Set Operational Modes. The WRCS provides the modes of operation discussed in the following paragraphs.

Laydown mode. The laydown mode is used to deliver retarded-type bombs. It may be used in conjunction with either the optical sight or a visual checkpoint. With either method, the desired range to target and release range are put into the system by manually setting the counters on the computer control panel.

When using the optical sight, the aircraft approaches the target at a predetermined speed and altitude, with a predetermined depression angle set into the optical sight. The pilot flies the aircraft in a straight course toward the target until the reticle pipper (on the optical sight) is superimposed over the target. (See fig. 4-1.) At this point, he depresses the bomb release switch and holds it depressed. The WRCS then computes the release point and releases the bomb at the proper point.

Dive laydown mode. The dive laydown mode is also used with retarded-type bombs and the system operates in a manner similar to the laydown mode. The major difference is that the radar is used to insert the initial range to target information. Release range is again put into the system by manually setting the counter on the computer control, but the optical sight reticle is set at zero depression.

A low approach is made to the target area (fig. 4-1). In the target area, the pilot causes the aircraft to climb until the target is visible and then dives the aircraft until the reticle pipper is superimposed over the target. At this time, the radar operator locks the radar, in the air-to-ground mode, on the target (fig. 4-1,A). This action supplies the ballistics computer with the radar slant range to the target. The pilot then depresses the bomb release switch, and pulls the aircraft out of the dive at a predetermined altitude and flies directly over the target. The WRCS will release the bomb at the proper moment.

Dive toss. The dive toss mode is used for releasing low-drag bombs. Low-drag bomb delivery does not require inserting release range and range to target into the

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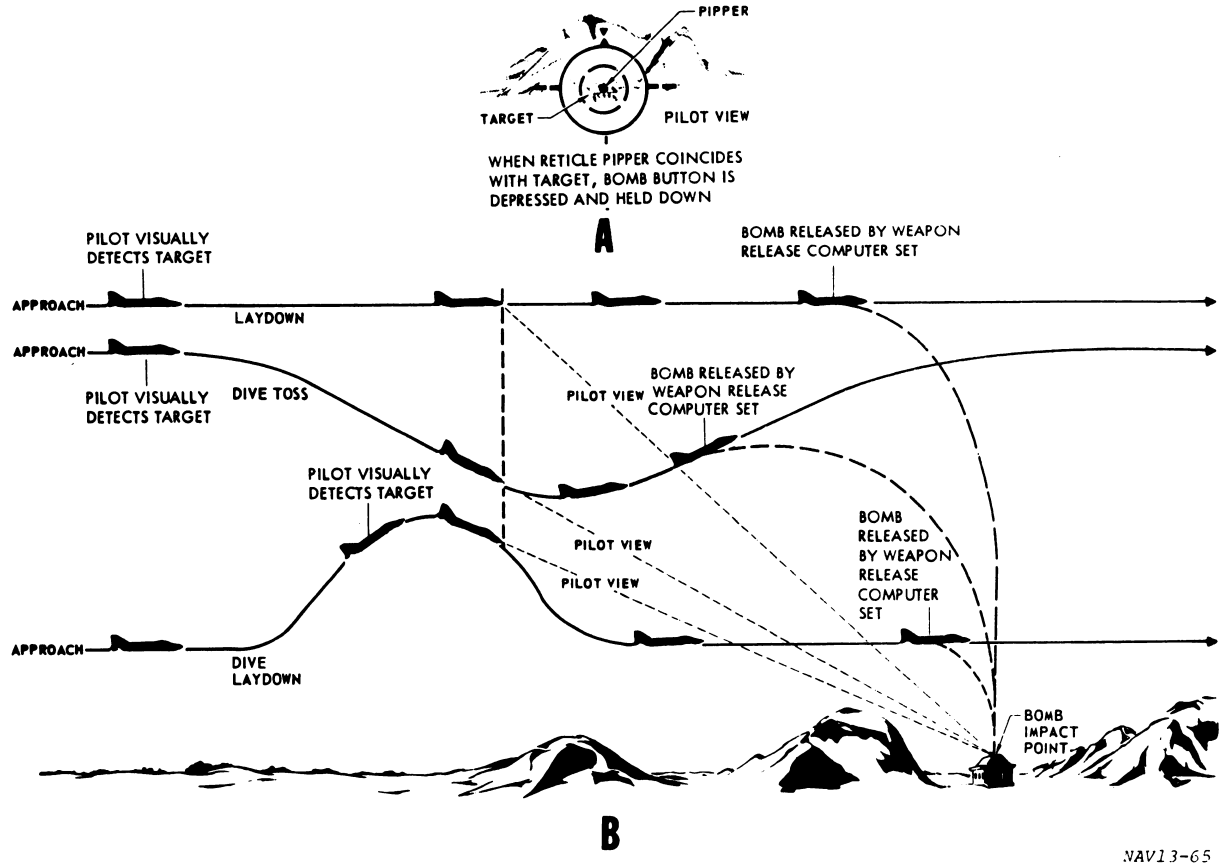

Figure 4–1. Weapons release computer set operational modes.

system, but a drag coefficient is required. The coefficient is put into the system by manually setting the coefficient counter on the computer control panel. The optical sight reticle is set at zero depression.

In this mode, the aircraft flies the same profile as that in the dive laydown mode (fig. 4-1) except when it pulls out of the dive. After pulling out of the dive, the aircraft starts climbing again instead of flying level. The pilot depresses the bomb release switch the same as he does in the dive laydown mode. The WRCS computes the proper release point to toss the bomb on the target. This mode allows the aircraft time to clear the area before the bombs detonate.

Offset bomb mode. The offset bomb mode is used to deliver retarded-type bombs. It is designed to assist the pilot in flying the aircraft to a target that is not radar identifiable. A checkpoint is chosen in the vicinity of the target that will provide a radar return. Refer to figure 4- 2,A. Target coordinates with respect to the checkpoint and target altitude must be known. These coordinates and altitude are preset into the computer control panel by manually setting the N-S distance, E-W distance, and altitude counters.

The pilot flies the aircraft until the checkpoint is picked up by the radar, which is operating in the map PPI mode. The radar pilot then positions the radar along-track and cross-track cursors over the radar checkpoint indication and depresses the FREEZE button. This action causes the cursors to track the checkpoint radar return. After cursor tracking of the checkpoint is established, the radar pilot depresses the target insert button. When this button is depressed, the N-S and E-W distances (entered in the computer control) are inserted into the computer. Now the cursors stop tracking the checkpoint and begin tracking the target location on the radar scope. At this point, target steering and bearing information is supplied to the pilot on the various instruments and indicator. After the aircraft is on the target run, the bomb release button is depressed, and the computer automatically provides the release signal which allows the bomb to release on target.

Target find mode. This mode is identical to that of the offset bomb mode, with the exception of *not providing a release signal for a bomb drop.* It aids the pilot in navigating from a determined location to a predetermined checkpoint, and then to the actual target area. An example of its use would be to update the INS navigation computer using the radar or visual identification point (IP) method.

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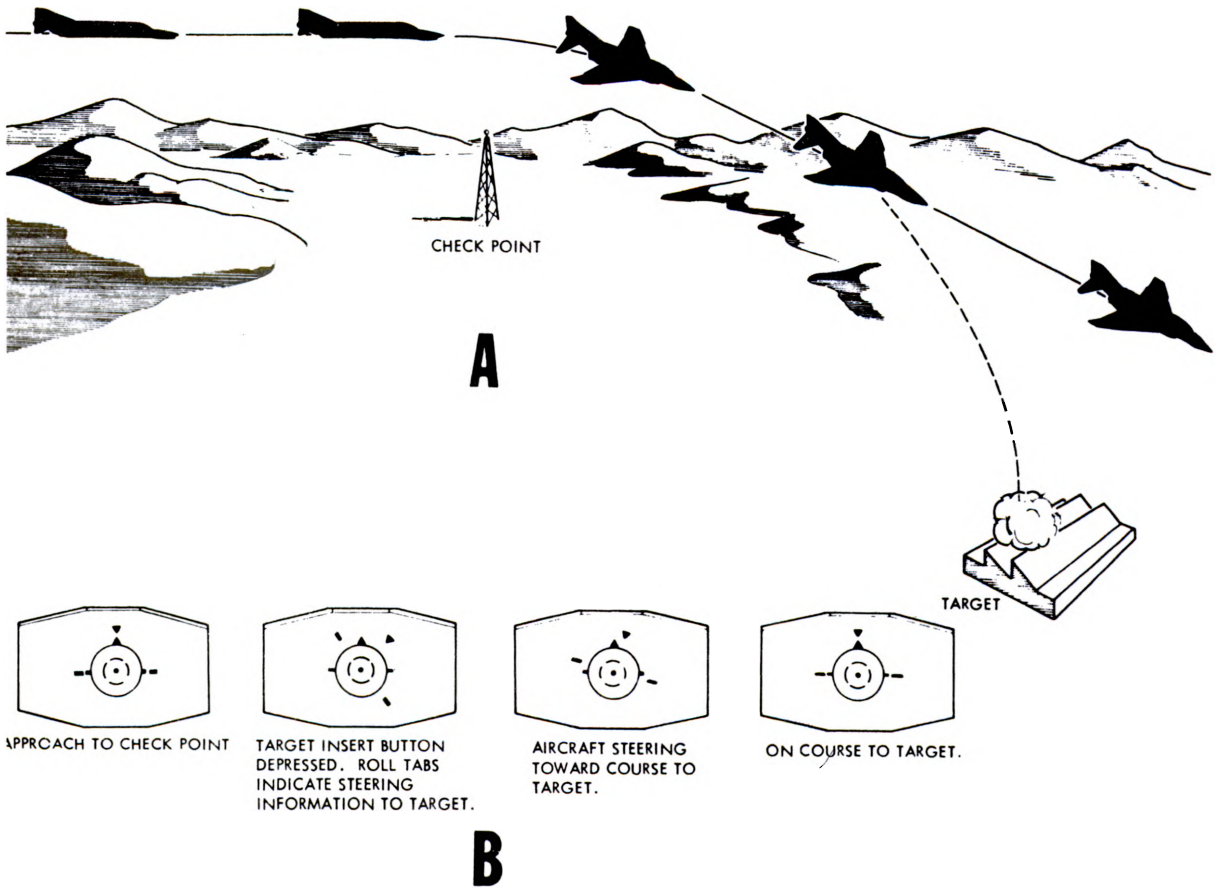

Figure 4–2. Offset bomb mode.

AGM–45 mode. The AGM-45 mode is used to launch Shrike air-to-ground missiles. This missile is designed to home-on and destroy radiating radar transmitters. Target altitude is manually inserted into the system, and the reticle depression is set to zero.

The WRCS computes the range to target and determines when the aircraft is within firing range. It also gives the aircrew an indication of the type of maneuver required to fire the missile at a given range, as shown in figure 4-3. These maneuver commands are either that of a climb, level flight, or a dive, as displayed on the angle of attack indexer lights in both cockpits. The WRCS provides a ready-to-fire signal, and after the pilot depresses the bomb release switch, computes the release signal for missile launch.

Exercises (A27):

1. How many operational modes does the WRCS have?
2. What three modes deliver retarded-type bombs?
3. What is the major difference in system operation between the laydown and dive laydown modes?
4. What is the major difference between the target find and the offset bomb modes?
5. Why must two modes use a checkpoint and what are the two modes?

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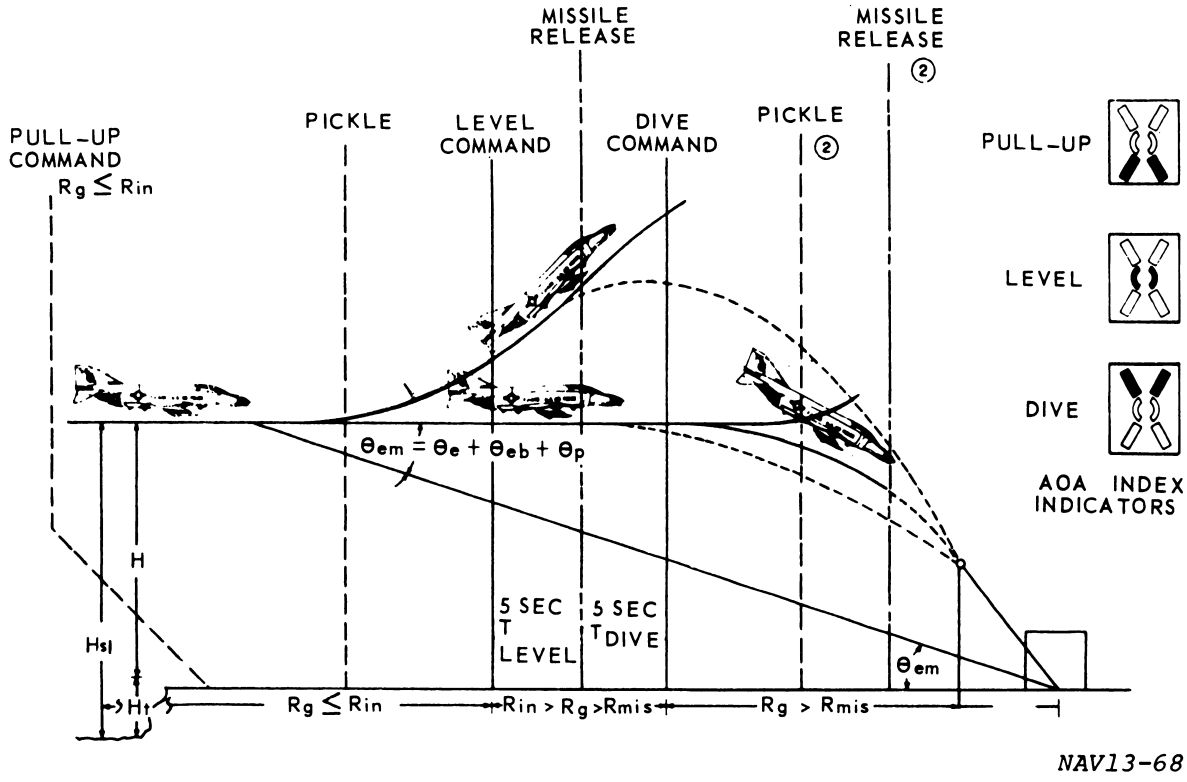

Figure 4–3. Missile mode profile.

6. The angle of attack indexer lights is utilized in what mode?

7. N-S distance and E-W distance counters are utilized in what mode(s)?

8. What is the purpose of the dive toss mode?

A28. State the purpose of the built-in test (BIT) and interpret a specified indication.

Built-In Test Mode. You may determine the operational status of the WRCS by performing a BIT. This test is accomplished by substituting fixed input signals for the normal system inputs and allowing the computer to solve the problem. This technique serves to isolate the WRCS for external inputs and allows a high degree of isolation from other avionic equipment.

To perform a BIT, select the mode to be tested with the rotary BIT switch on the computer control. Then set the counters on the computer control to their BIT readings, and depress and hold the BIT pushbutton switch while momentarily depressing the freeze pushbutton. If the computer solves the problem in 14 to 16 seconds, a GO indicator lights, showing the test is normal. If the computer solves the problem in less than 14 seconds or more than 16 seconds, the NO-GO indicator lights.

Exercises (A28):

1. What is the purpose of the built-in test (BIT)?

2. What is the indication if the WRCS solves a BIT problem in 17 seconds?

A29. Name the major components of the WRCS and give their functions.

WRCS Major Components. The computer set is made up of three major units. These are the ballistic computer, computer control, and computer-cursor control. Refer to figure 4-4.

Ballistics computer. The ballistics computer contains all of the analog circuitry required to solve

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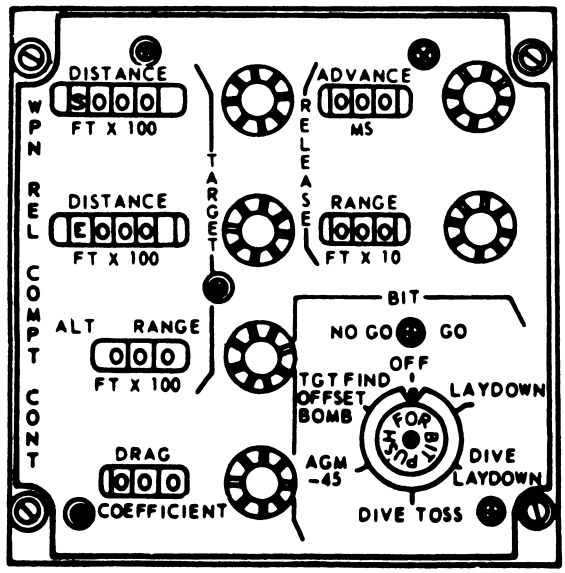
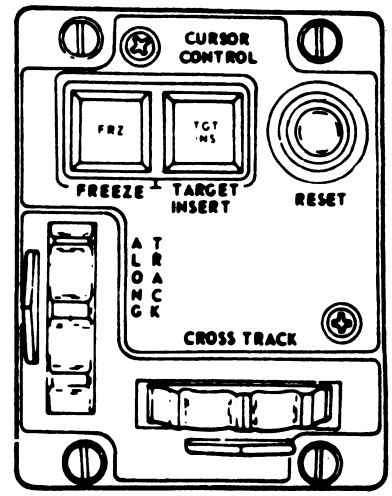


COMPUTER-CONTROL C-6480( )/ASQ-91



COMPUTER-CURSOR CONTROL C-6481( )/ASQ-91

Figure 4-4. WRCS control units.

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the bombing problem for each of the operational modes. It also contains the BIT circuitry to perform the built-in tests.

Computer control. The unit contains switches that allow the radar pilot to insert target distance, target altitude or range, ballistic drag coefficient of a low drag bomb, and release data in the form of time and distance. Target distance, target altitude or range, and drag coefficient are obtained from the aircraft ballistics table. The release advance control provides the capabilities of ripple weapons delivery. The timing is sequenced so that the first bomb detonates before the target, the second detonates on the target, and the remainder of the series detonate at intervals after the target. The computer control also contains the BIT mode selector switch, BIT pushbutton, and the FREEZE pushbutton to allow the radar pilot or maintenance personnel to self-test the system.

Computer-cursor control. This control contains two thumbwheels - the along-track and the cross-track. These thumbwheels allow the radar pilot to position the radar cursors on the checkpoint as displayed on the indicator. The computer cursor control also contains the FREEZE, TARGET INSERT, and RESET switches that are used by the radar pilot to insert target information into the computer which is used in the target find and offset modes, and to self-test the system.

Exercises (A29):

1. What are the three major subassemblies of the WRCS?

2. What is the purpose of the ballistics computer?

3. What is the purpose of the computer control and computer-cursor control?

4-2. Related Aircraft Systems and Components

The WRCS cannot operate by itself and independent of other aircraft systems. It must rely upon inputs from the INS and radar systems. There are, also, signals from the weapon control switch and bomb button. Outputs go to the lead optical sight system (LCOSS), horizontal situation indicator (HSI), bearing-distance-heading indicator (BDHI), and flight director group. In this section, we will discuss an overview of those systems and components that directly affect the WRCS.

A30. Identify the signal outputs of the INS used by the WRCS and the results if navigate mode signal is lost.

Inertial Navigation System (INS). Thirteen signals are supplied from the INS to the WRCS and are labeled in figure 4-5. You have already studied these in the INS volume and, therefore, should be familiar with them.

The power interrupt signal and navigate mode signal from the INS are monitored by the WRCS in all operational modes. If for any reason the navigate mode signal is lost, all power is removed from the WRCS power supply. During temporary power losses, the removal of the power interrupt signal prevents a release-signal generation until power is restored. The use of the other signals will be explained in detail later on. For example, in the laydown mode,

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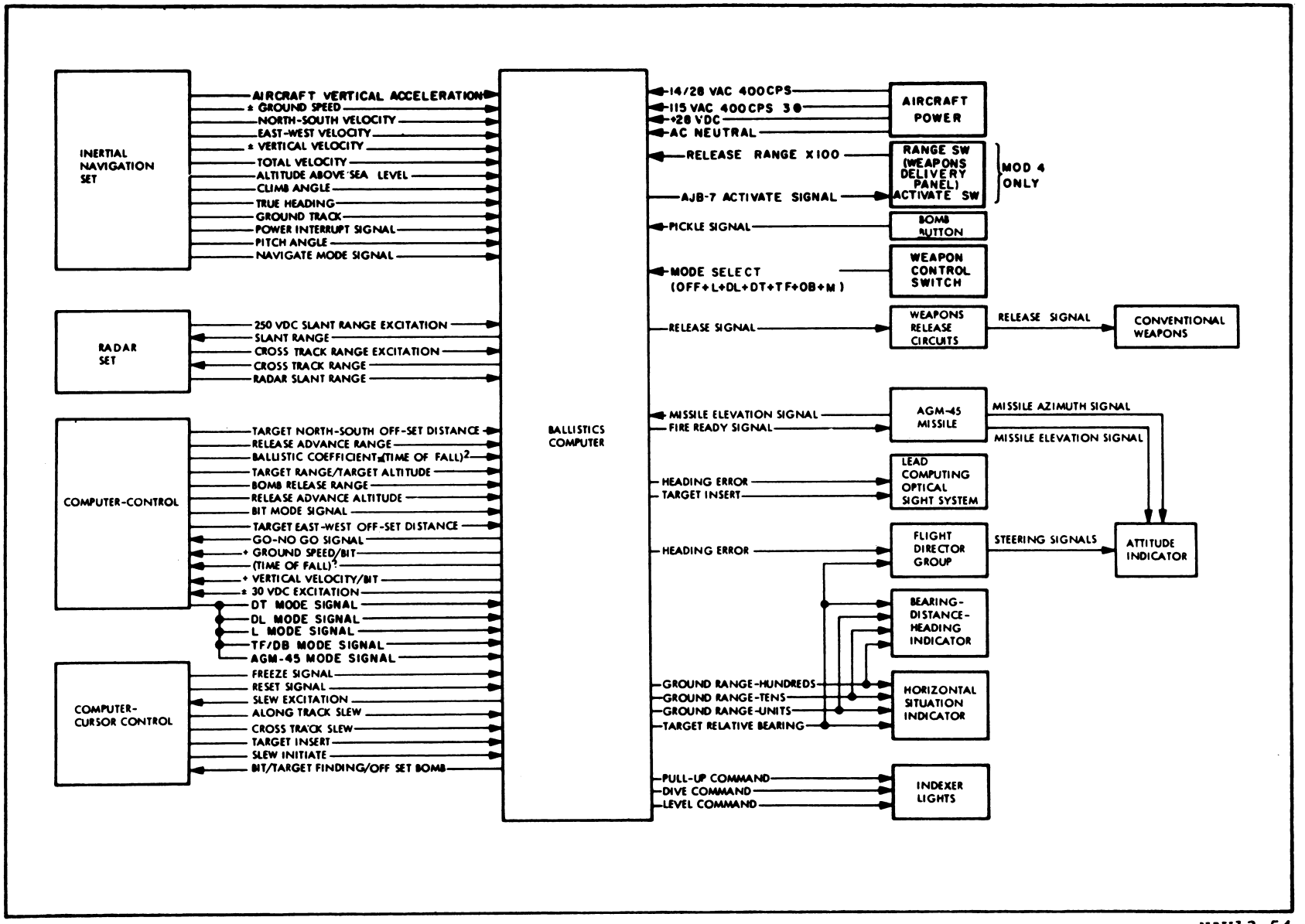

Figure 4–5. Weapons release computer set AN/ASQ–91 interconnecting diagram.

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groundspeed is used to compute the precise moment for bomb release and in the more complicated missile mode, groundspeed, pitch, altitude, and climb angle signals determine the proper release of the missile. You will see how each of these inputs is used in the detailed section on the six operational modes.

Exercises (A30):

1. What signal(s) does the inertial navigation system furnish the WRCS?

2. What happens to the WRCS if the INS navigate mode signal is lost?

A31. State the purpose of the lead computing optical sight system (LCOSS) and identify modes controlling the reticle presentation.

Lead Computing Optical Sight System (LCOSS). You will not perform maintenance on the LCOSS, but you should know how it operates in conjunction with the WRCS. Foldout 6 shows the display unit, a functional diagram of the system, and the reticle presentation. Follow on the foldout as an overview of the system is presented.

The LCOSS provides an electrically controlled reticle, which is displayed in the pilot's line of sight. The pilot uses this reticle image as a visual sight to fire guns or rockets, launch missiles, and release bombs. The aircraft is maneuvered to superimpose the reticle image center dot (pipper) over the target. When the pipper and target coincide, delivery of conventional weapons may be accomplished with optimum success.

The reticle image is projected onto the combining glass by a mirror in the optical display unit. This mirror is servo controlled by inputs from INS, WRCS, air data computer (ADC), and radar set. The reticle image can be positioned in elevation and azimuth. The reticle image roll tags can be rotated and the range analog bar can vary in circumference length. These movements are determined by the mode of operation.

The roll tabs indicate aircraft roll attitude or steering information. In the laydown, dive laydown, dive toss, and missile mode, they indicate aircraft roll altitude. In the target find and offset bomb modes, they indicate steering-to-target.

Elevation position of the reticle on the combining lens is determined by either pitch stabilize reticle depression setting, reticle depression setting, or a fixed AC voltage. In the laydown mode, pitch input and the reticle depression setting are combined to control the elevation position. In the missile mode, only the reticle depression setting controls the elevation position. In the dive toss, dive laydown, target find, and offset bomb modes, the reticle is caged to radar boresight (-2° elevation) by a fixed AC voltage.

Azimuth position of the reticle image is either drift signal corrected, or it cages to radar boresight (0° azimuth). In the dive toss, dive laydown, and laydown modes, azimuth positioning is drift corrected. In the target find, offset bomb, and missile modes, azimuth reticle image position is caged to radar boresight.

The range analog bar displays target range and appears whenever the radar is locked on. In other words, it is the range that the radar is locked on and not necessarily what appears inside the pipper. These positioning signals are summarized on foldout 6,B.

Exercises (A31):

1. What is the purpose of the lead composing optical sight system?

2. In which modes is the reticle depression control used?

3. What controls the azimuth position of the reticle in the dive laydown mode?

A32. List the inputs and outputs between the radar set and WRCS.

Radar Set. The radar set is used to search for and detect targets. Once a target is located, the radar can be locked on the target and will then automatically track it. When locked on a target, the radar provides target range and position.

Looking at figure 4-5, we can see that the radar set supplies the WRCS with 250-VDC slant range excitation, cross-track range excitation, and radar slant range signals.

Remember that during dive laydown and dive toss modes, the WRCS utilizes the radar set slant range output. However, during target find and offset bomb modes, the WRCS must utilize slant range excitation and cross-track range excitation to compute slant range and cross-track range. The WRCS slant range and cross-track range outputs are applied to the radar set to position the range and offset cursors.

Exercises (A32):

1. What output signals from the radar set are used by the WRCS?

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2. What output signals from the WRCS are used by the radar set?

A33. Identify important signals from various aircraft switches.

Aircraft Switches. We have not, as yet, discussed how we can turn the WRCS on or off, or how the different modes of operation can be selected. In fact, there is no switch located on any WRCS control panel that will control either of these functions.

The mode of operation is selected by the LABS/WPN Rel (low-altitude bombing system/weapon release) switch located on the main instrument panel of the aircraft (see fig. 4-6). This switch, in addition to other functions, selects the WRCS mode of operation or turns the WRCS off.

Another cockpit switch of importance to the WRCS is the bomb release switch (stores release switch). This pushbutton switch is located on the control stick grip assembly, as seen in figure 4-6. Depressing it produces the so-called *pickle signal* and causes the ballistics computer to start computing release time. Depressing the bomb release switch does not immediately release the weapon but gives the computer permission to start computing a release point. After the release point has been computed and upon reaching that point, then the computer will generate a release signal.

Exercises (A33):

1. What WRCS signal comes from the LABS/WPN Rel switch?

2. What WRCS signal comes from the bomb release switch?

4-3. Detailed Analysis of the Weapons Release Computer Set (WRCS)

The WRCS AN/ASQ-91 is an analog computer, as opposed to a digital computer release system. This means that there is a continuous analogy of the bombing problem, instead of only one set of punched or keyed data. You also recall that the system is made up of three major assemblies: the computer control, the computer cursor control, and the ballistics computer. In a combined operation, these units computer range, determine course directions, and develop the automatic weapon release signal in five modes of operation for bombing and air-to-ground missile firing. Release signals are necessary in the bombing modes, which are laydown, dive laydown, dive toss, and offset bomb. There is no release signal generated in the target find mode, but range-to-target and steering signals are provided. The AGM-45 (Shrike) missile mode requires maneuver commands and a release signal from the system for proper operation. Each mode is designed to be used according to the weapons aboard and the bombing situation. As you study the diagrams of each mode, you will find that many circuits are used in more than one mode.

A34. Cite selected functions in the laydown mode circuitry and state the purpose of various circuit components.

Laydown. The first mode of the WRCS is the laydown mode. This mode is used to release retarded-type bombs in level flight. For the first part of our discussion, we will refer to figure 4-7, which shows the bombing problem of the laydown mode.

First, the pilot has previously set the release range into the computer by manually adjusting the release range knob to the desired range, and has set the target range in by manually setting the target range knob. Now he sets the reticle depression knob to obtain the depression angle for the target range and altitude. When these conditions have been met, the aircraft is flown at a predetermined altitude. When the reticle aiming dot appears on the target, as seen at B position of the aircraft in figure 4-7, the ground range to the target is equal to the target range that was previously set into the computer. When the aiming dot and the target coincide, the pilot depresses the bomb release button and holds it depressed. This causes the computer to integrate the ground velocity, thus supplying a constant ground range-to-go signal. When the range to go minus the delay time and advance time equals the preset release range, the computer develops a release signal and the bombs drop. You can see in figure 4-7 that the release signal is developed slightly before the aircraft reaches the release range. This allows for the rack delay and the release advance.

Referring to foldout 7, you can trace the signals through the computing system in the laydown mode. Start at the lower left corner of the foldout and we will trace the groundspeed signal from the output signal distribution unit of the inertial navigation system. The groundspeed signal ($+V_g$) enters the ballistics computer on 1J2, pin t, and goes to R76 and 1J1, pin Z. You position potentiometer R76 to adjust the rack delay and produce the delay signal $+V_g\ T_c$. The signal is then fed through K47, which is energized only in dive toss mode, and K10, which is energized only in AGM-45 mode, to summing resistor A3R98. The $+V_g$ signal also leaves the ballistics computer on 1J1, pin Z, enters the computer control on 2J1, pin j, and is applied across R2B. The output of R2B is the release advance signal ($V_g\ T_a$). This signal returns to

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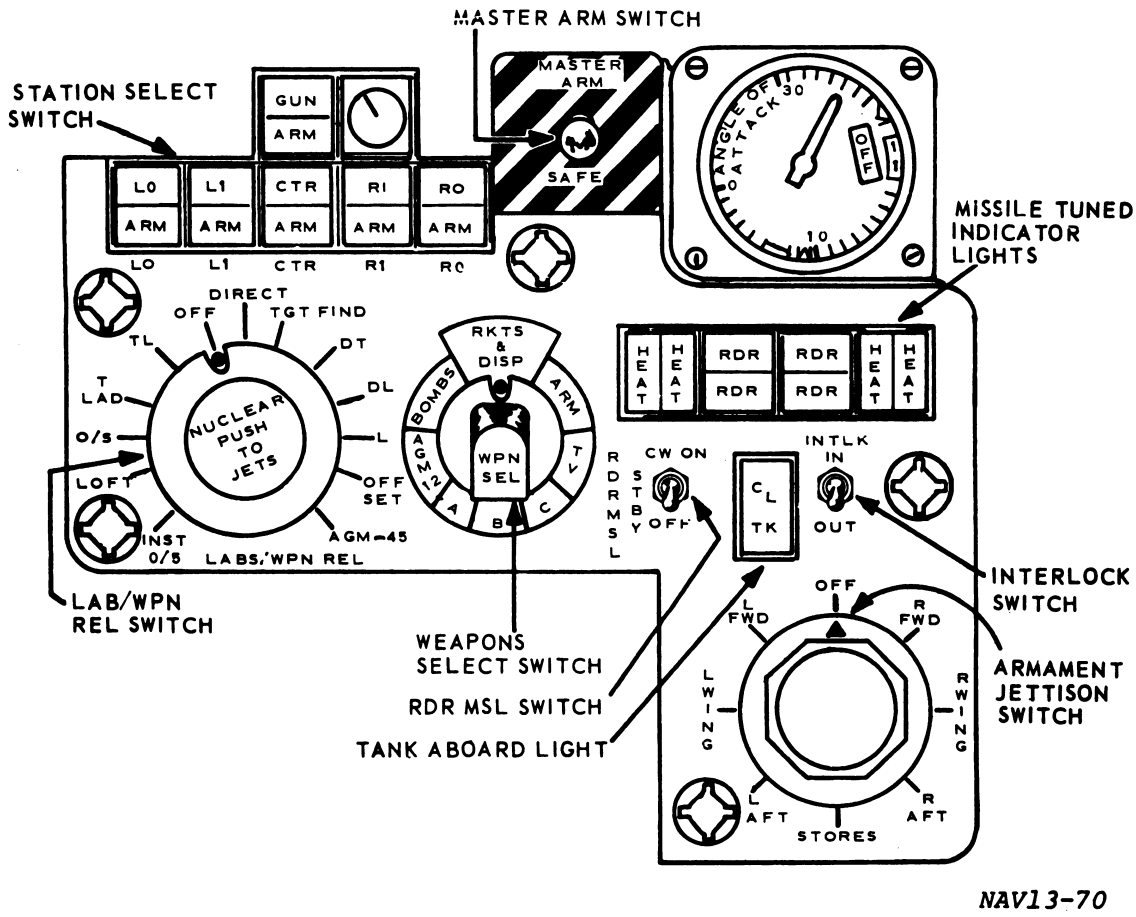

Figure 4–6. WRCS switches.

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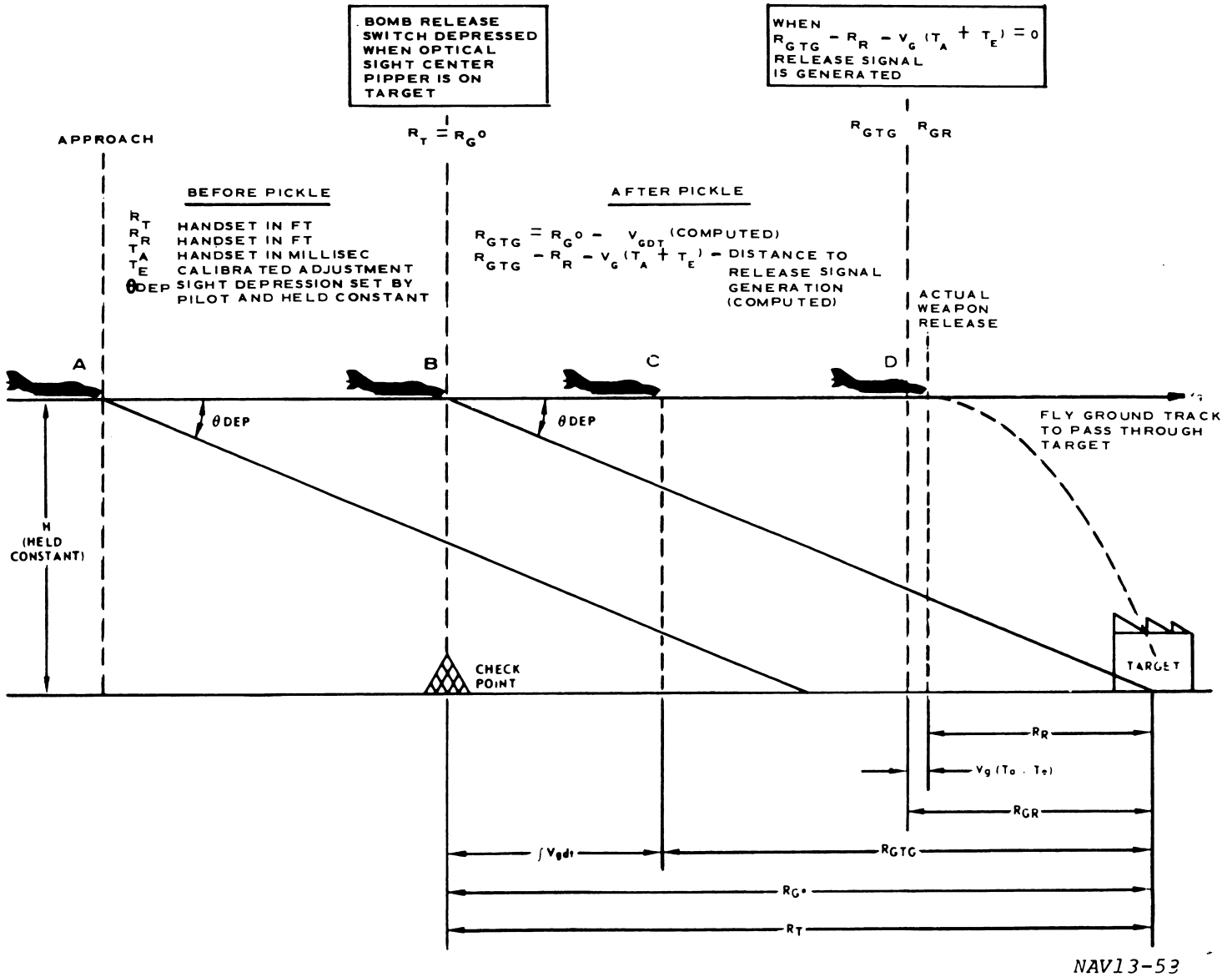

Figure 4–7. WRCS laydown mode profile.

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the ballistics computer, entering on 1J1, pin $\overline{x}$. Next, $+V_g\ T_a$ goes through K11 missile relay and K46 dive toss relay to summing resistors A3R97.

Now, if you look at 1J1, pin n, you can see that a -30-VDC leaves the ballistics computer here and goes into the computer control on 2J1 pin H. The -30-VDC is used to energize the target range potentiometer R6. The output of R6 is a voltage representing target range ($-R_T$) and is returned to the ballistics computer on 1J1 pin N. From here the $-R_T$ signal goes through relay K26, which is closed in the laydown mode, as you will see later when we discuss the control circuits for the laydown mode. From relay K26 the $-R_T$ signal goes to the summing resistor A3R101.

You will also find that +30-VDC leaves the computer on 1J1, pin V, enters the computer control on 2J1, pin G, and energizes potentiometer R5. The output of R5 is the preset release range (R_R) and leaves the control on 2J1, pin p. The R_R signal enters the computer on 1J1, pin J, and is fed through relays K10 and K46 to summing resistor A3R96. All of these inputs ($+R_R$, $-R_T$, $+V_g\ T_a$, and $+V_g\ T_c$) are summed up at the junction at the right of A3R101 and applied to summing amplifier Σ 4A. For the time being, let us leave this circuit and see how the control circuits operate in the laydown mode.

Start tracing the control circuits at the 28-VDC circuit breaker. The power from the breaker enters the computer on 1J2, pin C, and leaves the computer on 1J1, pin X. The power then goes through the normally closed contacts of the BIT switch and to the LABS/WPN Rel switch in the attitude reference bombing computer. When the switch is placed in the LAYDOWN position, 28-VDC is furnished to the ballistics computer through 1J2, pin G. This energizes relays A1K18, K19, K20, K21, K22, K23, K24, K25, K26, and K27. Relay K41 is also energized at this time provided K40 is deenergized. K40 is only energized when the BIT switch is depressed. The other relay in this group, K60, is energized as long as the power to the inertial navigation system is not interrupted.

With all of the preset inputs to the computer and with the control relays energized, you are ready to learn how the computer operates. As shown in foldout 7, the groundspeed signal $-V_g$ from the INS is applied to the computer through 1J2, pin $\overline{u}$. From here the signal goes through the deenergized contacts of K31, through deenergized contacts of K51 at pickle and K24, to amplifier DC2. You have already seen how K24 is energized; and when we get to the release circuits, you will see how K42 and K51 are energized. Relay K42 is now open, ungrounding the input to DJ2. Amplifier DC2 is an integrator amplifier, which uses the groundspeed ($-V_g$) to determine the range to go to target. The range-to-go-to-target signal is then fed through the deenergized contacts of K4A and K48 to the summing point at the input of summing amplifier Σ 4A. At the summing point, we now have signals representing the corrected release range ($R_R - R_T + V_g\ T_a + V_g\ T_c$) and the range-to-go-to-target signal ($\int_o^t V_g\ dt$). Before you trace this part of the circuit any further, you must energize some more relays.

Earlier in this chapter we mentioned that, when the pilot had maneuvered the aircraft to a point where the target and the aim dot on the sight coincided, he depressed the bomb release button. If you look in the upper right corner of the foldout 7, you will find 28-VDC fed to one side of the bomb release button. When the bomb release switch is depressed, 28-VDC goes through the deenergized contacts of the direct relay, lockout relay 2, and to contacts of pickle signal transfer relay (PSTR). If you check back you can see that placing the LABS/WPN Rel switch in LAYDOWN position energizes the PSTR. This allows the 28-VDC to pass on to K64 in the ballistics computer. This places 28-VDC at terminals 3 and 7 of relay K64. When terminal 8 of K64 is at ground potential, the relay is energized. At the same time, this 28-VDC is also applied to relays K42 and K51, causing them to energize.

Originally, the input to the summing amplifier was $+ R_R - R_T - V_g\ T_a - V_g\ T_c$, or release range minus the target range. This signal is applied to summing amplifier Σ 4A where it is amplified and fed to comparator CA1. The output of CA1 is a positive voltage, which is fed through relays K60 and K41 to terminal 8 of K64. Since this signal is positive, relay K64 is not energized. When the pilot depresses the bomb release button, relays K42 and K51 are energized. This allows the groundspeed ($-V_g$) to be applied to the integrator. The output of the integrator represents the range to go to target. When this range to go to target is equal to the release range minus the target range, the voltage at the summing point becomes zero. This causes the summing amplifier and the comparator to have a zero output, effectively placing terminal 8 of K64 at ground potential. This energizes K64 and allows the 28-VDC to energize relay bomb release relay (BRR). Energizing relay BRR applies 28-VDC to the intervalometer and pedestal assembly or to the special weapon relay panel, depending on the position of BBTR (bomb button transfer relay).

We still have a few circuits in the No. 4 miscellaneous relay panel that we have not discussed. First, look at the direct relay. This relay is energized when the LABS/WPN Rel switch is in the DIRECT mode. When the direct relay is energized, you can see that you have a release signal immediately upon depressing the bomb relay button. The other three relays are the INS OUT (inertial navigation systems out), LOR-1 (lockout relay 1), and LOR-2 (lockout relay 2). These relays operate to prevent a release signal from being generated when the inertial navigation system is inoperative.

The INS sends a 28-VDC signal to the INS out relay located in the No. 4 miscellaneous relay panel. When the INS out relay is energized, its contacts apply 28-VDC from the bomb release button to LOR-1. This energizes LOR-1 and allows the pickle signal to pass through the lower contacts and on to the ballistics computer. The upper contacts of LOR-1 apply

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28-VDC from the LABS/WPN Rel switch to LOR-2, causing it to energize. The upper contacts of LOR-2 lock the relay in the energized position. In the event of a failure of the INS, the 28-VDC is no longer present and the INS out relay is deenergized. When the lower contacts of the INS out relay open, LOR-1 is deenergized. However, LOR-2 remains energized through its upper contacts. Under these conditions, there is no path for the 28-VDC from the bomb release button to K64; thus, no release signal is generated. Also, this prevents the pickle signal from energizing relays K42 and K51. This opens the contacts of K51 and prevents the $-V_g$ signal from entering the integrating circuit. In other words, if the INS fails, the computer ceases its computation and it is impossible to obtain a release signal.

Exercises (A34):

1. Where does the groundspeed signal enter the ballistics computer?

2. What is the purpose of R6 in the computer control?

3. What signals are summed at the input of Σ 4A in the laydown mode?

4. When is K41 energized?

5. What is represented by the output of amplifier DC2?

6. When does the output of comparator CA1 become zero?

7. What is the purpose of relays INS out, LOR-1, and LOR-2?

A35. Cite specified input and output characteristics of the dive laydown mode circuitry.

Dive Laydown. There are many similarities in the circuit of the laydown and dive laydown modes. The manually set-in signals, such as release range, release advance, and rack delay time, are exactly the same. However, there is one major difference—the method of obtaining target range. You will recall that range to target is a resistive value that is manually set in during the laydown mode. The value used in the release equation during the dive laydown mode is computed. The signals that are needed for this computation are slant range and pitch angle, which are provided by the WRCS and INS, respectively.

Before discussing the circuit operation of this mode, let us review some trigonometric functions necessary for better understanding. By observing figure 4-8, you will see how the trigonometric functions are applied to altitude and range problems. The functions necessary for understanding the equations used in dive laydown, dive toss, and target find/offset bomb modes are sine and cosine. As the aircraft pitches or climbs, angles are developed by the INS that must be used to compute for range and altitude. In figure 4-8, you can see that range (R_g°) is calculated by using the cosine function $\frac{\text{adjacent}}{\text{hypotenuse}}$. At a given pitch angle (θ_p - 2°) and with the hypotenuse (H) equal to a known value of the radar slant range (R_s) such that

$$\text{Cos } (\theta_p - 2°) = \frac{A}{R_S}$$

then the adjacent side would be equal to $R_s \sin \theta_p - 2°$. Side A is equal to side A′, then A′ is equal to $R_s \cos (\theta_p - 2°)$. Although we are not concerned with altitude computations in this mode, we can see that it will be computed by the same method by using the sine function.

Considering the foregoing explanation, let us now take a look at the dive laydown circuit (fig. 4-9) and see how it compares with the laydown circuit. This figure shows that the slant range signal from the radar set enters the ballistics computer on 1J3 pin U. From here the signal goes through the normally closed contacts of BIT relay K29 and dive toss relay A1K53 to the contacts of relay A1K18, which are closed when the LABS/WPN Rel switch is placed in the DIVE LAYDOWN position. From relay A1K18 the signal goes through resistor A1R51, the now closed contacts of relay A1K18, and the now closed contacts of K20 to the center tap of the cosine potentiometer in the pitch servo. Let us leave this circuit for now and trace the pitch signal coming in from the INS.

The pitch signal enters the ballistic computer on 1J2 pins P, BB, and AA and passes through the normally closed contacts of BIT relays K28 and K29. From here the signal goes through dive laydown relays K20 and K21, which are closed when the LABS/WPN Rel switch is in the DIVE LAYDOWN position to the CT synchro in the pitch servo. The pitch servo operates to position the wiper arm on the cosine potentiometer.

We now have two inputs to the cosine potentiometer, the slant range signal and the pitch angle position.

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The output of the potentiometer is the product of the slant range and pitch angle and is equal to the ground range to target (R_{GO}).

The $-R_{GO}$ signal then passes through relays K25 and K14, summing amplifier Σ1A, and relays K26 and K24 to the output circuit of DC2. From this point on, the circuit is the same as the laydown circuit. In other words, the only difference in the two modes is that in the laydown mode the target range is set into the system manually, whereas in the dive laydown mode the target range is computed from the slant range and pitch angle inputs. In both cases, the release circuit operates in the same manner.

Exercises (A35):

1. What inputs remain the same in DIVE LAYDOWN position as they were in LAYDOWN position?

2. Where does the slant range enter the ballistics computer?

3. Where does the pitch signal enter the ballistics computer?

4. What is represented by the output of the cosine potentiometer?

A36. Cite the location of inputs in the dive toss mode circuitry and state the purpose of various circuit components.

Dive Toss. This mode is best described by reference to the basic laws of gravitation as defined by Sir Isaac Newton. Not to imply that Newton was goofing off, but, as you know, he was sitting under an apple tree when the idea hit him. He described this phenomenon in terms of distance, velocity, and acceleration, terms which could be used with any other falling object. With the advent of modern technology and warfare allowing flight over the enemy, a great number of weapon systems have been designed with these considerations in mind. In this mode of delivery, we might

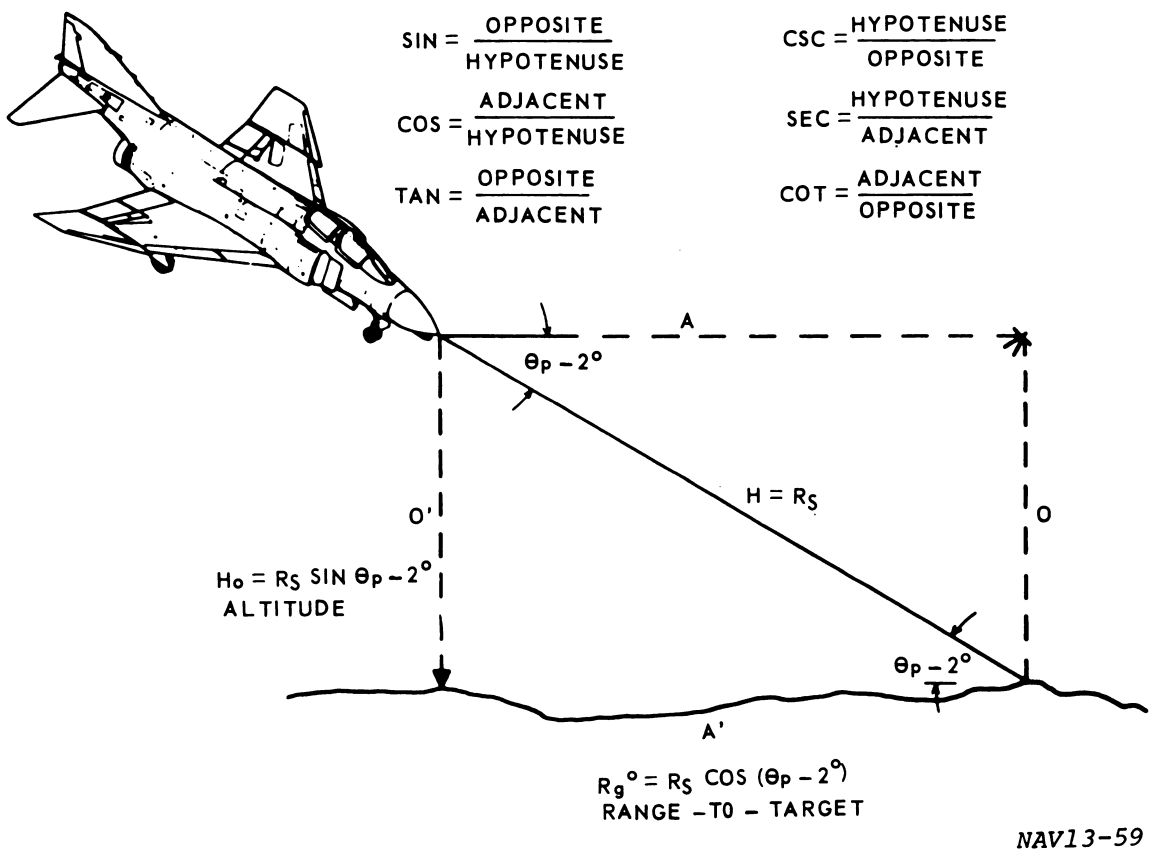

Figure 4–8. Altitude and range trigonometric functions.

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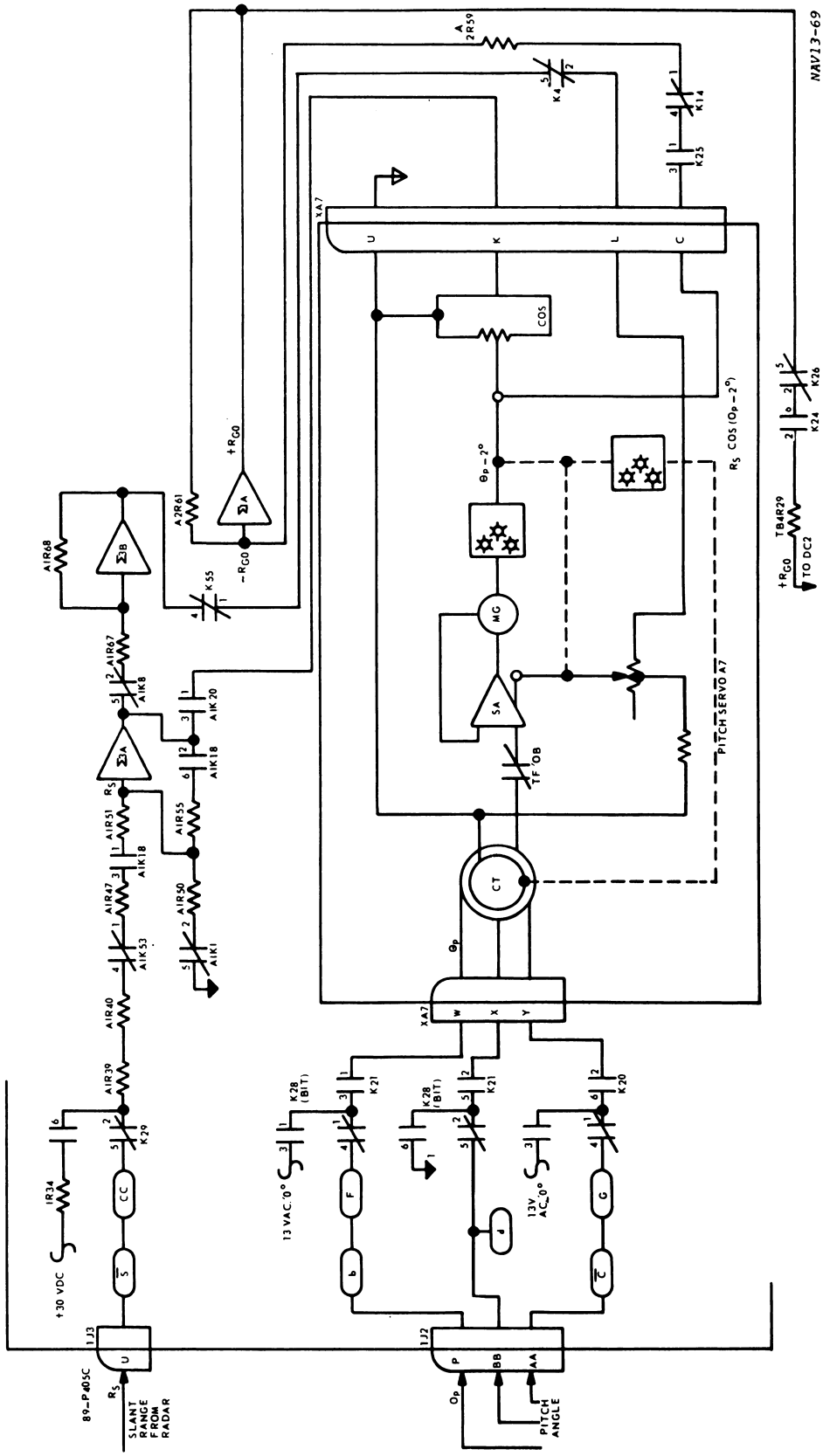

Figure 4–9. Dive laydown mode partial function.

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begin with an equation which may be used to solve for time, distance, and velocity. This equation is $d = vt$. The time component in our WRCS equation becomes time of fall (t_f) which can be equated as $t_f = \frac{d}{v}$. The distance coefficient is initial range ($R_g°$), and the velocity component is the aircraft velocity as measured by the INS (V_g). Substituting these values into the equation makes our equation become $t_f = \frac{R_g}{V_g}$. With this established as a premise, we must now consider not only a moving object but one which is falling. This is where Newton's Law of gravitation comes into play. Newton says that $d = \frac{1}{2} gt^2$. The distance through which the object must fall is computed as an altitude signal (H) and substituting this and our first formula into Newton's formula makes his formula become:

$$H = \frac{1}{2} g \left(\frac{R_g°}{V_g}\right)^2$$

If in this equation we transpose the altitude to the same side of the equation as the velocity, the equation becomes equal to 0.

$$0 = -H + \frac{1}{2} g \left(\frac{R_g°}{V_g}\right)^2$$

This then is the basic equation that must be solved by the computer. By design considerations, when this occurs, the release equation is solved, and upon solution of the equation, a bomb or weapon would be automatically released.

By observing figure 4-8, you will see that the diving aircraft establishes the initial altitude because of the pitch angle and slant range. Altitude is produced as a function of the sine of the pitch angle or $R_s \sin \theta_p - 2°$. This happens to be the initial altitude that occurs when the target and reticle pipper are coincident; but as the aircraft continues to dive, this value changes (see fig. 4-10,A). The vertical velocity (V_v) is a measure of how much the altitude is changed; thus, the integral of this value will give instantaneous values of altitude. Our altitude factor now becomes

$$-R_s \sin \theta_p - 2° + \int_0^T V_v \, dt$$

After the bomb release button has been depressed, the need for providing initial altitude and range has been supplied. So, as a result, the function potentiometers may be used for other purposes. At bomb release (pickle), the excitation of the sine and cosine potentiometers is changed to represent ejection velocity (V_e) rather than altitude and range. This force (V_g) is perpendicular with the longitudinal axis that goes from the nose to the tail of the aircraft. As the aircraft pulls up in a wings level climb, and with the bomb button depressed, the trigonometric functions of ejection velocity are generated. These signals are going to add to or subtract from the vertical velocity signal (V_v) and groundspeed (V_g). In figure 4-10,C, you can see that the $V_e \sin \theta_p - 2°$ will be added to the groundspeed signal (V_g), and the $V_e \cos \theta_p - 2°$ will be added to or subtracted from vertical velocity signal (V_v). The latter depends on whether the aircraft is in a climb or a dive.

Now, look at the mechanization of the electrical components. Using foldout 8, we can see that when the LABS/WPN Rel switch, located at zone 1D, is placed to the DIVE TOSS position, the necessary relays are energized (see zones 7E, 8E, and 9E). The pitch angle from the INS (zone 1A) is applied to the pitch servo A7 through 1J2, pins $\overline{p}$, BB, and AA. An error signal from the servoamplifier positions the sine and cosine potentiometers (zone 8A). The slant range signal input (zone 12A) is applied to 1J3, pins s and U, and provides excitation to the two function potentiometers in the pitch servo A7. Since these potentiometers are positioned to the pitch angle of the aircraft, their wiper arms provide altitude and range signals. The sine potentiometer provides $R_s \sin (\theta_p - 2°)$ to DC1 and Z1 to charge the network to a value equal to initial altitude. The cosine potentiometer output $R_s \cos (\theta_p - 2°)$ is applied to DC2 and Z2 to charge this network to initial range. The altitude signal from DC1 is amplified and applied to the summing networks entering summing amplifier 4A (zone 9D). The range signal R_g is applied from DC2 to the ground range servo A10 (zone 10E) for the development of the time of fall component. The $-V_g$ signal from the INS (zone 1A) is applied into the computer at 1J2 pin $\overline{u}$. This signal continues to the ground range servo A10 and provides excitation for followup potentiometer R1B. This signal, when used as feedback, provides a division function, so R_g is being divided by V_g. You will recall from our earlier derivation of the release equation that $\frac{R_g}{V_g}$ is equal to time of fall (t_f). This time of fall signal is extracted from R1A and reapplied to excite R2A which produces $(t_f)^2$. The time of fall squared output from R2A is then amplified and applied out 1J1, pin a (zone 5E) to excite R1 of the computer control. This resistor is positioned by the drag coefficient set-in knob and applies a signal back to the computer as $1/2\ C_B\ (t_f)^2$ to summing amplifier 4A.

Foldout 8 shows that, at pickle, 28-VDC is applied through bomb button contacts (zone 2B) and energizes the pickle relays K42 and K51 (zone 11C). The contacts of these relays are in the input and feedback circuits of amplifiers DC1 and DC2. When relay K42 is energized, the amplifiers become integrator amplifiers because of the substituted capacitive feedback for resistive feedback. Relay K51 connects inputs of $-V_g$

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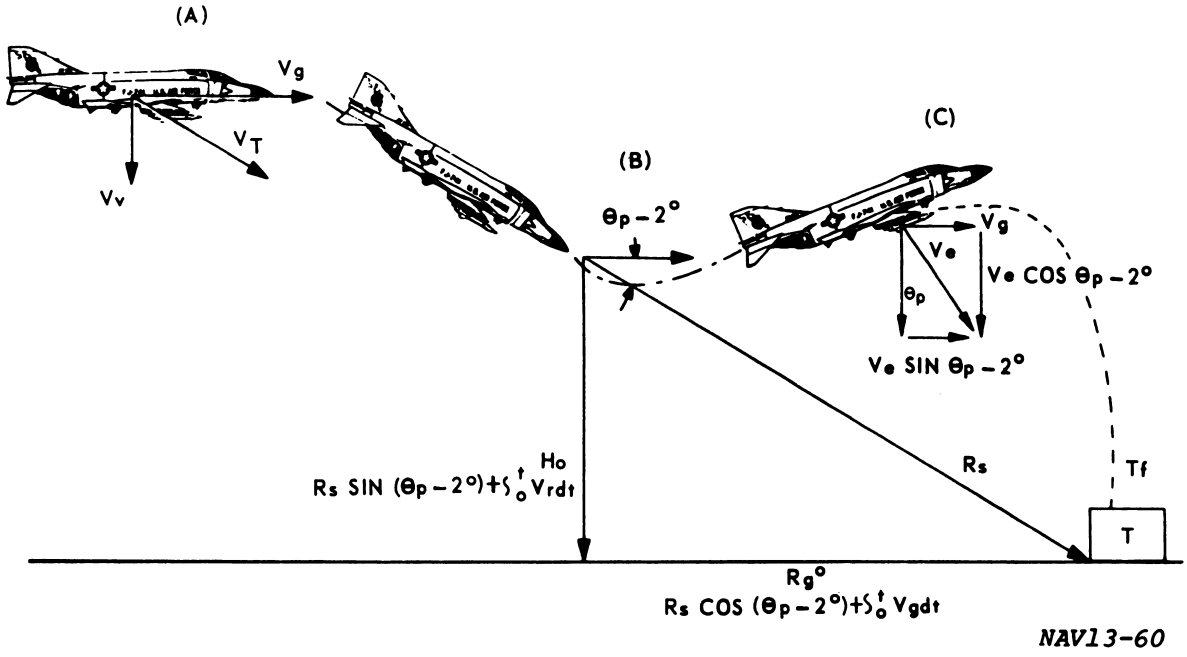

Figure 4–10. Dive toss profile.

to Z2 or the initial range circuit, and energizes relay K52 in the dive toss mode. Relay K52 connects inputs of $-V_v$ to Z1 or the initial altitude circuit to be integrated. Also at pickle, relays K53 and K54 (zone 9E) are energized and switch the excitation of the function potentiometers in the pitch servo A7 from slant range to ejection velocity. A voltage representing this velocity is derived from R36 (zone 10B). You, as a mechanic, will adjust this resistor to the proper value, and it will remain fixed.

The sine and cosine functions of V_e are algebraically summed with V_g and V_v to provide signals representing time of fall and altitude changes to the comparator CA1 (zone 10B). The additional factors of release advance and rack delay times are provided by the excitation of $+V_g$ to the resistors R2A and R2B in the computer control and R76 of the ballistics computer (zone 6B). These signals are all summed in amplifier 4A to be forwarded to the comparator CA1. When these inputs are summed and their values are equal to zero, the comparator provides an output ground to cause relay K64 to energize. Then, energized relay K64 supplies 28-VDC out 1J2, pin F, to energize the bomb release relay 30–K304, which, in turn, provides 28-VDC to the pedestal panel and intervalometer (zone 14D) to produce a release signal. This is the mechanization of the dive toss mode, and release can occur in a wings level pullup between −45° to +10°. The lockout relays in the No. 4 miscellaneous relay panel function as they did in the laydown mode to prevent generating a release signal when the inertial navigation system is inoperative. This panel also prevents the release circuit from responding if the pilot depresses the bomb release button a second time during a bomb run.

Exercises (A36):

1. To what servo is the pitch angle applied?
2. Where does the slant range enter the ballistics computer?
3. What unit produces $(t_f)^2$?
4. What causes DC1 and DC2 to become integrator amplifiers?
5. What is the purpose of R36?

A37. State differences of and inputs to the target find and offset bomb modes.

Target Find and Offset Bomb. Now, take a look at the target find and offset bomb modes. These two modes operate the same except that no release signal is developed in the target find mode. In these modes, the inputs are as follows: true heading (θ_H), velocity north (V_N), velocity east (V_E) true ground track (θ_T),

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altitude (H_{SL}), groundspeed (V_g), release advance ($V_g T_a$), release range (R_R), target altitude (H_T), and target distance north (D_N). Already you can see several new inputs; however, the computer still operates in the same way as in the modes we discussed earlier.

In these modes, the pilot places the along-track and cross-track cursors on the radar return of the checkpoint. Next, he presses the FREEZE button. This action establishes the aircraft position in relation to the checkpoint. When the pilot presses the target insert button, the coordinates of the target (D_N and E_E) are added to the computer.

The V_N and V_E signals from the INS are integrated to give the present position of the aircraft. These signals are compared with the target distance signals D_N and D_E to provide the pilot with steering information to allow him to fly to the target. If the system is in the offset bombing mode, a release signal is developed to drop the bomb on target. The true heading and true ground track signals are used to correct for aircraft drift.

The actual circuitry of these two modes is much the same as that of the modes we have previously discussed. The main difference is the use of bearing/ground track servo, ground range servo, cross-track servo, slant range servo, and pitch servo. The cross track servo uses the slant range and bearing to target minus the ground track angle to develop a signal representing the cross track ground range to target signal. The slant range servo develops a signal which is proportional to the slant range. This signal is used in the radar to position the cursor. It also furnishes a signal proportional to the slant range to the bearing/ground track servo. The bearing/ground track servo receives inputs of range east (R_E) and range north (R_N) and resolves them into a target bearing (θ_{BT}) signal. This servo also resolves the slew along track (S_{AT}) and slew cross track (S_{CT}) signals into north and east components used to correct the R_E and R_N signals. The ground range servo provides a signal which is proportional to ground range to the pitch servo. The pitch servo develops a signal proportional to the sighting elevation angle (θs) which is used as an input to the slant range servo.

To improve our understanding of the operation of this mode, let us look at some of the necessary mechanization of components and the manner in which their outputs are used. By viewing figure 4-11, we can see that the direction of the aircraft when positioned in respect to true north develops an angle referred to as true heading (θ_T). This angle is used when the operator positions the along track and cross track cursors. First, when the along track c ırsor is positioned over the checkpoint, it produces s ne and cosine functions of slew along track (S_{AT}). Second, when positioning the cross track cursor over the checkpoint, additional values of sine and cosine slew cross track (S_{CT}) are generated. As shown in figure 4-11, combinations of these signals derive the north-south and east-west position of the checkpoint. The mechanization of these signals is shown in figure 4-12. On the right side of the figure you see the along track and cross track thumbwheels. These thumbwheels, when positioned, provide selected voltages to a DC resolver containing two decks. The resolver is positioned as a function of true heading (θ_T). Deck A provides outputs of slew along track, while deck B produces outputs of slew cross track. Because of the connections of the resolver, the wiper arms produce both sine and cosine outputs. Then we see that summing resistors combine the proper signals for cursor positioning.

When the cursors are positioned along the checkpoint, the operator depresses the FREEZE button on the cursor control unit. This unit sums integrated velocity inputs from the INS with this initial position to allow for tracking the incoming checkpoint. At the point when the operator determines the target can be displayed on the indicator, he depresses the target INSERT button and causes preset values of distance north (D_N) and distance east (D_E) to be added to the checkpoint position. The cursors then move to the known position of the target with respect to the checkpoint.

The offset bomb mode is identical with the target find mode and has a bomb release signal provision for retarded-type weapons. The manual inputs, in addition to those required for the target find mode, are the desired release range (R_R) set on the computer control release range counter; and if weapon ripple delivery is desired, the required time interval is set to the computer control release advance counter. The mission proceeds in the same manner as for the target find mode with the aircraft guided in accordance with the steering signals obtained from the WRCS. The bomb release button is then depressed; and when the range to target equals the preselected release range, together with the release advance and rack delay compensations, the ballistics computer supplies a release signal to the bomb release circuitry.

Exercises (A37):

1. What is the major difference between offset bomb and target find modes?

2. What are the inputs in target find and offset bomb modes?

A38. State the inputs to the AGM–45 mode and the purpose of various circuit components.

AGM–45 (Missile). Now, let us see the differences in the missile mode. First, the inputs are as follows: altitude (H_{SL}), climb angle (θ_C), groundspeed ($+V_g$ and $-V_g$), total velocity (V_t), target altitude (H_t), and

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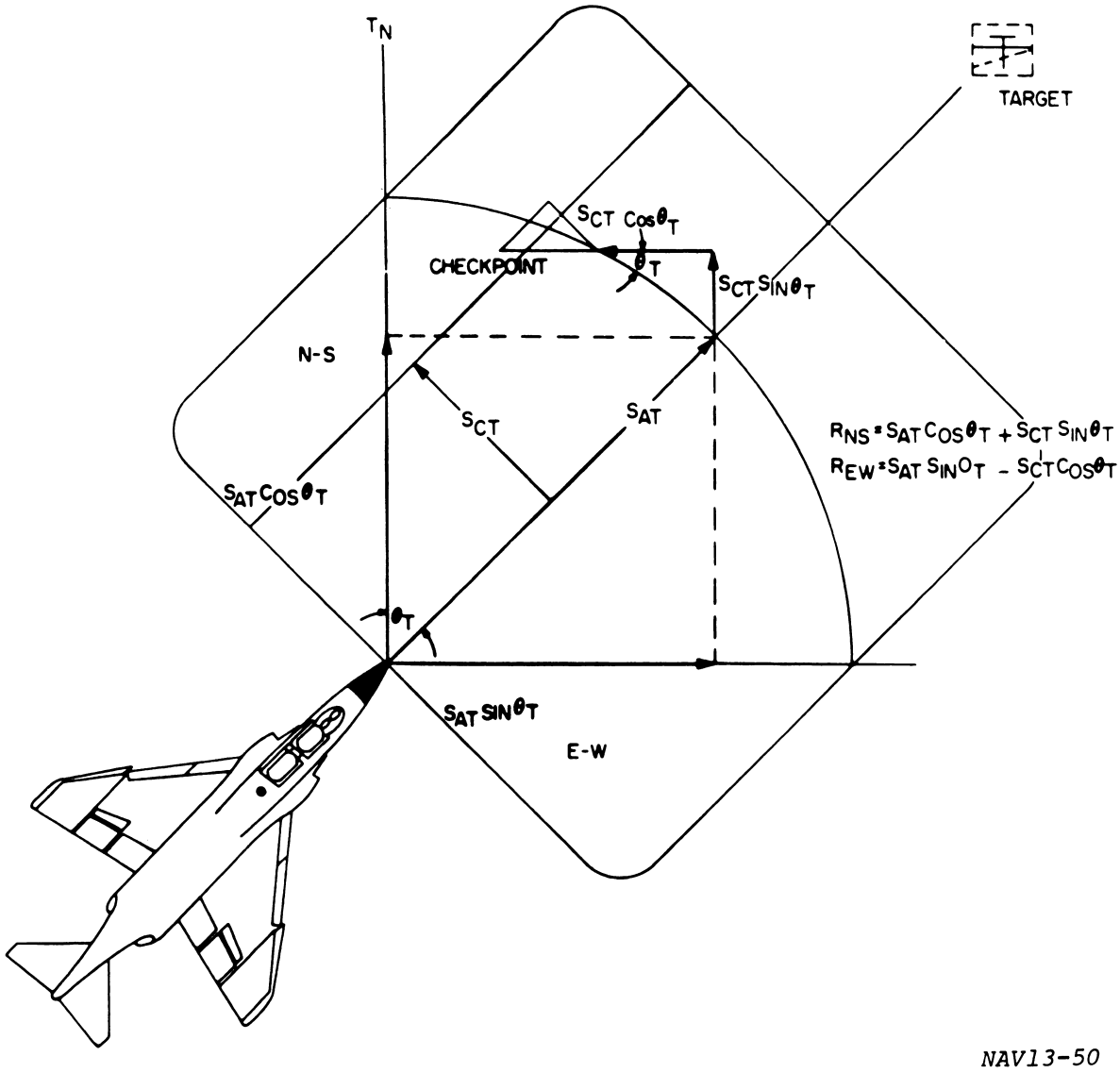

Figure 4–11. Cursor resolution.

release advance (V_g T_a). The other major difference is the vertical maneuver commands. These commands are displayed on the angle of attack indexer lights in both cockpits. When the ground range to target is less than the missile in-range signal, a pullup command is displayed on the angle of attack indexer lights. Then, 5 seconds before release time, a level command appears. This command lasts for 5 seconds after release time when a dive command appears. As soon as the level flight indicator lights and the bomb release button is depressed, a fire ready signal is sent to the wing nylon connectors to energize the power supplies of the missiles. The actual release is determined by the output of a comparator, which places 0 volts on the ground side of the release relay when the missile equation is zero.

The foregoing paragraph describes briefly the operation of the AGM-45 mode; but for an increased understanding, let us discuss some of the components and their mechanization to allow for proper operation. To begin, the Shrike missile is a weapon that detects a radiating type target and informs the pilot of such detection through an audible headset tone. At this time of detection, the missile supplies elevation and azimuth error steering signals to the attitude director indicator (ADI). The pilot then maneuvers the aircraft toward the radiating source or until the steering error is indicating null on the ADI. When a null signal is attained, it indicates not only course direction but also angle of depression of the target. Soon thereafter, the pilot can depress the bomb release button and select one of an option of three releases. These options are pullup, level, or dive. For any of these options there are certain necessary computations—one of which is ground range. In other modes, this computation is either manually set in or derived as a result of pitch

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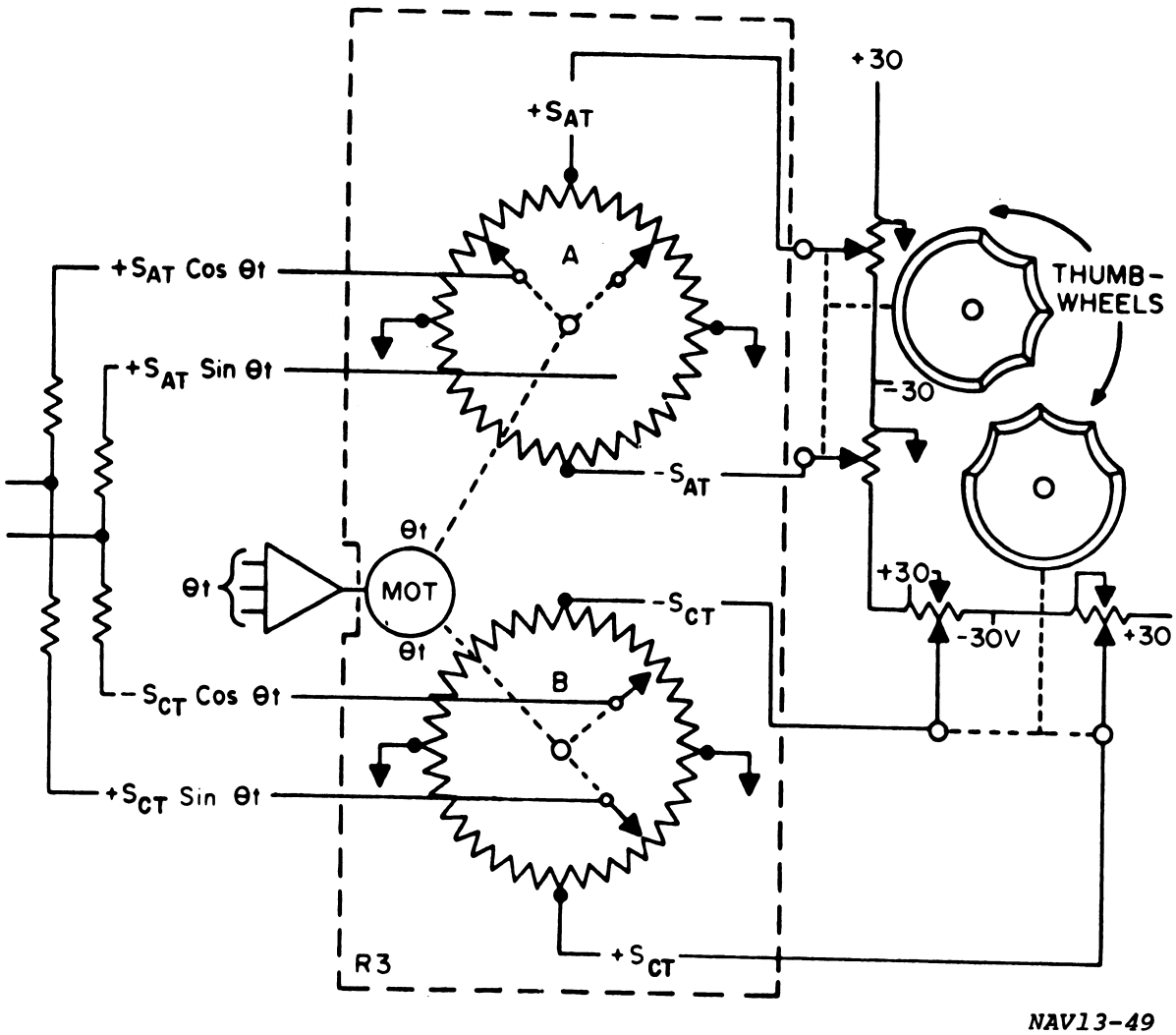

Figure 4–12. Resolution of SAT and SCT.

angle of the aircraft and slant range of the radar. The missile mode, however, uses a similar but different method in its computation. Use figure 4-13 for the following discussion. This mode uses summation of aircraft pitch angle (θ_p), missile elevation bias (θ_{eb}), and missile look angle (θ_e) to obtain missile elevation angle (θ_{em}).

$$\theta_{em} = \theta_p + \theta_{eb} + \theta_e$$

This angle, along with the altitude of the aircraft (H_{sl}) less the target altitude (H_t), can be used to compute ground range. This computation, of course, would be a tangent function which is mechanized by the pitch servo A7 in the following manner:

$$\text{Tan } \theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{H}{R_s}$$

and using the trigonometric identity that states:

$$\text{Tan } \theta = \frac{\sin \theta}{\cos \theta}$$

and with θ driving the servo to position the sine and cosine potentiometers, then:

$$\text{Tan } \theta_{em} = \frac{H}{R_s} = \frac{\sin \theta_{em}}{\cos \theta_{em}}$$

and, solving for R_s, we find that:

$$R_s^\circ = \frac{H \cos \theta_{em}}{\sin \theta_{em}}$$

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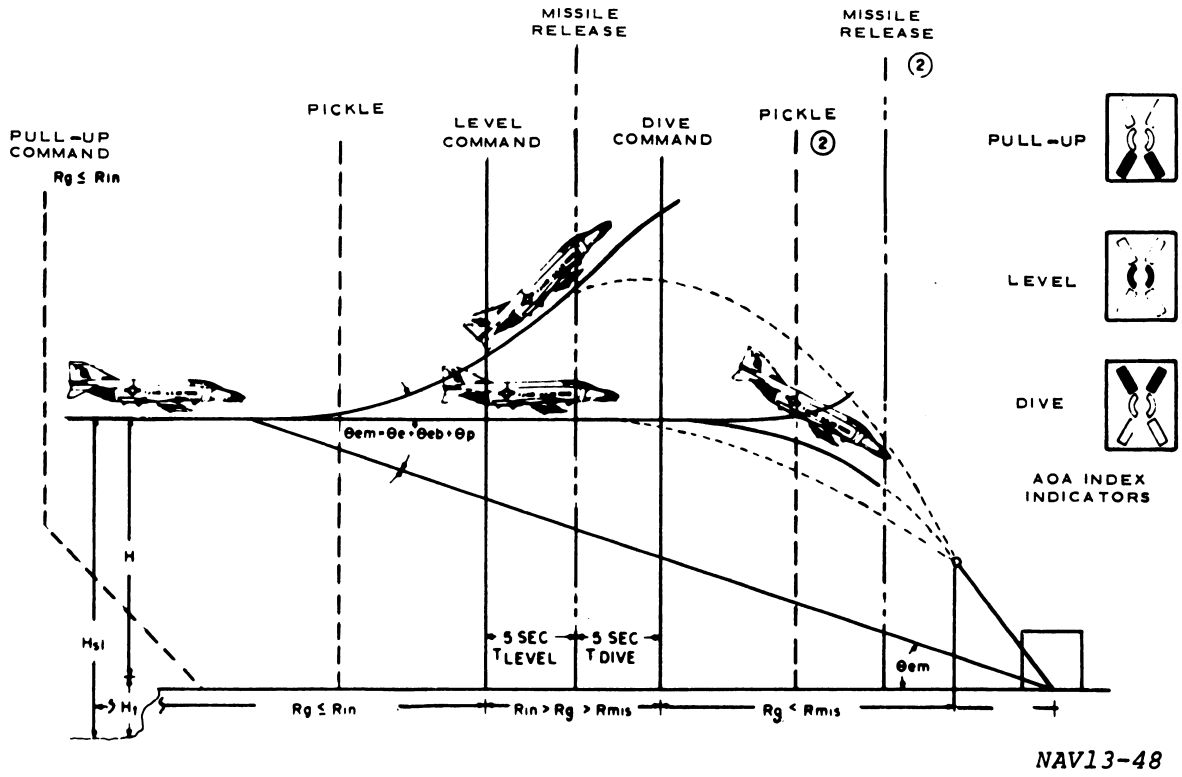

Figure 4–13. Consolidated missile mode profile.

This ground range is then applied to each of the indicators (HSI and BDHI) to provide a distance readout and is applied to summing amplifier 4A to solve for the release equation. The pilot depresses the bomb release button and begins a wing level climb. Release occurs 5 seconds after the equation for level release is solved.

The missile release sequence is dependent upon the comparison of ground range (R_g) with either a fixed in-range signal or a computer missile range (R_{mis}) signal. (Notice the dashed line envelope in fig. 4-13.) When $R_g \leq R_{in}$, the pullup light illuminates. To initiate a level release command, the WRCS must perform the missile range (R_{mis}) computation by summing climb angle (θ_c), altitude above sea level (H_{sl}), and total velocity (V_t), or

$$R_{mis} = \theta_p + H_{sl} + V_t$$

Then, when R_g becomes equal to the sum of missile range (R_{mis}) minus release advance ($V_g T_a$) and range bias (R_b), the level indicator illuminates. By observing figure 4-13, you can see that a release signal occurs 5 seconds after the level command is presented. This means that if the pullup maneuver is ignored, a level release occurs 5 seconds after the level command appears. If the level command has been ignored, another 5-second interval causes the dive indicator to illuminate. The pilot must immediately assume a dive maneuver, because that is the last possibility of an accurate release.

Exercises (A38):

1. What are the inputs necessary for the AGM-45 mode?

2. What units are used to indicate maneuver commands in the AGM-45 mode?

3. What servo computes ground range?

4. When does the level indicator illuminate?

4-4. Built-In Tests

The WRCS may also be checked by means of built-in tests. The tests on the weapons release computer are made by inserting given inputs into the computer and allowing the computer to solve the problem. If the

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computer solves the problem in 14 to 16 seconds, a GO indicator lights, showing that the test is normal. If the computer solves the problem in less than 14 seconds or more than 16 seconds, the NO-GO indicator lights. In this case, you will find it necessary to check the WRCS further in order to locate the malfunctioning unit.

A39. Trace the WRCS built-in test circuits and state operating principles of relays and the routing of signals.

The BITs consist of feeding fixed signals into the WRCS and obtaining an indication of satisfactory solution of the problem by the computer. For our discussion, we will use foldout 9 and trace the BIT circuitry for the laydown mode. First of all, the target range (R_T) is set at 17,000 feet, the release range (R_R) at 5000 feet, and the release advance (T_a) at 900 milliseconds. These inputs are fed directly to the ballistics computer and to the summing point just as they are in the laydown mode.

In order to make the laydown BIT checks, the BIT mode switch on the computer control must be in the LAYDOWN position. Now, when the BIT switch is depressed, 28-VDC is applied to 1J1 pin Y and point FF to energize BIT relays K28, K29, K31, K32, K33, K35, K37, K40, and K66, as shown in figure 5-14. On foldout 7 you can find that, when K40 is energized, its contacts open and cause K41 to deenergize. This, in turn, opens the contacts of K41 in the comparator circuit and prevents a release signal from developing during the BIT. When relay K31 is energized, it disconnects $-V_g$ from the integrator circuit and substitutes a scale value from the −30-VDC supply in its place. However, the −30-VDC cannot get through K51 until it is energized. Also, relay K32, which is now energized, removes the $+V_g$ signal from the rack delay circuit and substitutes a +30-VDC in its place. We can see that all of the inputs are fixed and that the computer will solve the equation and produce a comparator output that would normally produce a release signal. However, instead of a release signal, the BIT circuitry produces a GO indication on the computer control. Actually, there is one more requirement to initiate the BIT. The FREEZE button must be depressed. This energizes K51 and furnishes a simulated groundspeed input to the integrator. (This circuit is not shown on either FO 7 or fig. 4-14.)

Now, refer again to figure 4-14 which shows the BIT relay logic. When the FREEZE button is depressed, power is applied to the time delay circuit. After a period of 14 seconds, the time delay circuit produces a 2-second output which is applied to relay K58. Relay K58 is then energized for 2 seconds. This energizes K56, which locks itself in the energized position. At the end of the 2-second period, relay K58 becomes deenergized, returning to its normal state.

Depressing the FREEZE button also applies 28-VDC to K57 and to K42, K50, and K51 which energizes these three relays. K51 feeds the simulated negative groundspeed signal to the integrator. The integrator feeds its output to the comparator. When the output of the comparator becomes zero, the lower end of relay K57 coil is at ground potential and the relay is energized. The inputs used in the BIT are selected so that the solution time of the weapons release computer should be 15 seconds ± 1 second.

What happens when the computer takes less than 14 seconds to solve the problem? For example, let us assume that the computer solves the problem in 10 seconds and produces a release signal at that time. Under these conditions, relay K57 energizes 10 seconds after the FREEZE button is depressed. Since the time delay circuit does not have an output at this time, neither K58 nor K56 is energized. This leaves the relay contacts of K56, K57, and K58 in a position where 28-VDC from the BIT switch is applied to relay K59, causing it to energize. If we look at figure 4-14, we can see that energizing K59 applies 14/28-VAC to the NO-GO lamp and at the same time breaks the circuit to the GO lamp.

Next, consider the condition where the computer takes more than 16 seconds to solve the problem—say 20 seconds. Under this condition, K58 has been energized for 2 seconds, allowing K56 to energize and lock in the energized position. Then, at the end of the 2-second period, K58 deenergizes. Since a release signal has not been developed at this point, 28-VDC passes through contacts 1 and 3 of K56, 1 and 4 of K58, and 5 and 2 of K57 to energize K59. Again, K59 causes the NO-GO indicator to light. Notice also that should K57 now become energized, there is no path for current to light the GO indicator.

Finally, let us see what happens under normal circumstances; that is, when the computer solves the problem in 14 to 16 seconds. If the comparator output becomes zero 14 to 16 seconds after the FREEZE button is depressed, K56, K57, and K58 are all energized at the same time. This allows 14/28-VAC from 1J2 pin N to pass from 1 to 4 of K59 and 1 to 3 of K57 and energize the GO indicator. Notice that at the end of 16 seconds K58 becomes deenergized; however, if we trace the 14/28-VAC circuit, we find that the GO indicator remains energized.

Once a BIT has been performed, we must press the reset button to return the circuits to their starting condition. We can see in figure 4-14 that depressing the reset button breaks the circuit and causes relay K1 and the time delay relay to deenergize. This places the circuitry in a condition where the computer is ready for us to perform a BIT in another mode.

The only difference in the BIT circuitry in the other modes is the inputs to the comparator circuit. These inputs are all obtained either from the computer control settings or from scale voltages of the + and -30-volt supplies. These inputs are selected by the BIT relays energized in the selected position of the BIT mode switch.

The BITs give us only a GO or NO-GO indication. They give us no indication of what is wrong when we

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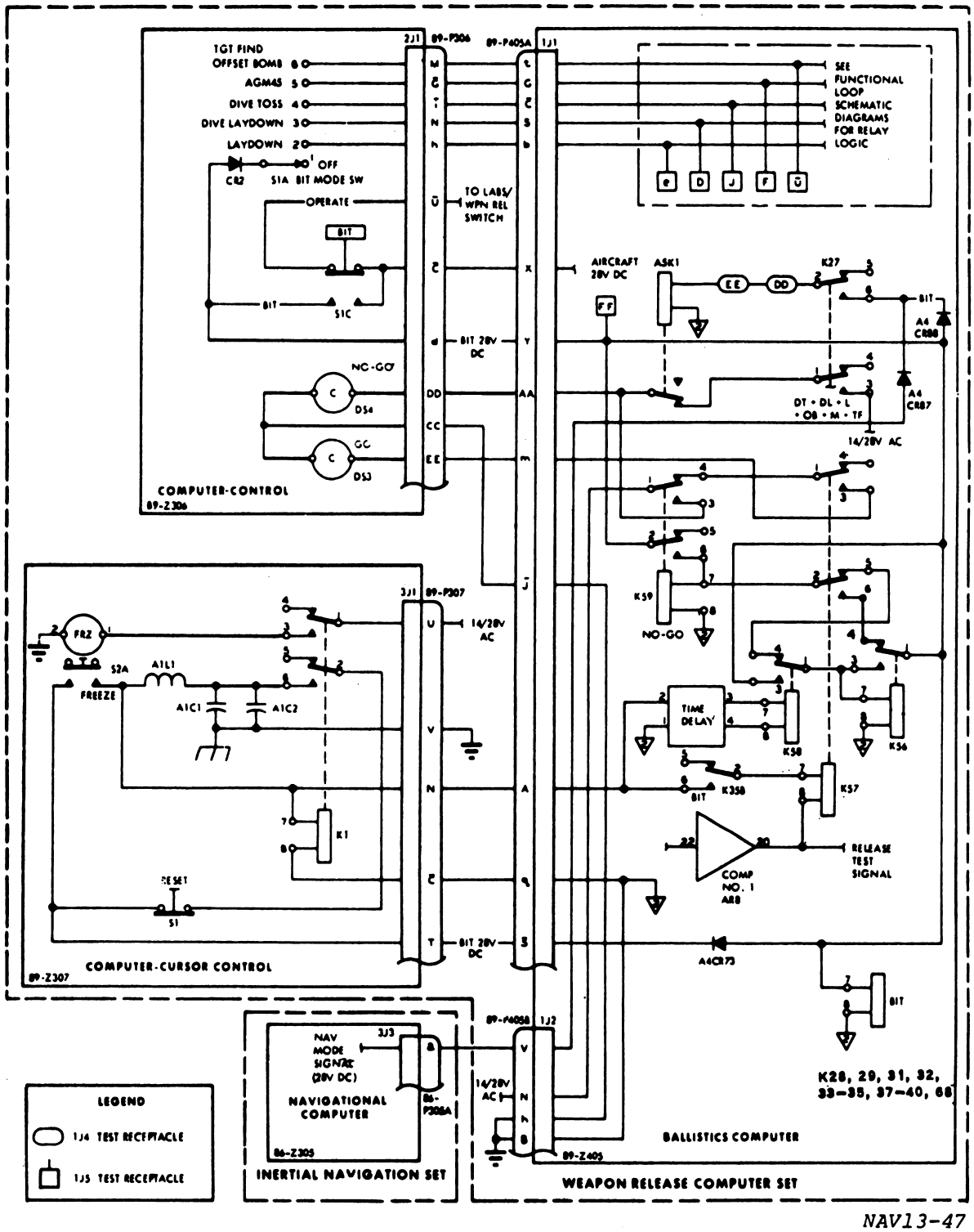

Figure 4–14. Modules circuit.

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get a NO-GO condition. In some cases, we may be able to localize the trouble by noting the modes in which we get a NO-GO condition and analyzing the circuit to determine what components are used when we get the NO-GO condition and are not used when we get a GO condition. In order to determine the location, we must make other system tests using special test equipment.

Exercises (A39):

1. What BIT relays are energized when the BIT switch is depressed and the system is in laydown mode?

2. What relay prevents a release signal from being generated during BITS?

3. For what period of time is K58 energized?

4. What relay energizes the NO-GO indicator?

5. What relay energizes the GO indicator?

6. Why must the reset button be depressed after performing a BIT?

4-5. WRCS Maintenance

In this section, we will cover the checks, adjustments, and troubleshooting procedures that you may have to perform on the WRCS. In our discussion, we will not go into the step-by-step procedures for making each check and adjustment. Instead, we will discuss the use of technical orders in performing the checks and adjustments. In all cases, when you check or adjust the WRCS, you must follow the technical order procedures. These are the only authorized procedures for system checkout and adjustment.

Since it is necessary to check out the system in order to determine operational status, we will start with a discussion of the different checks. These checks are also used in the troubleshooting procedures discussed in this section.

A40. Identify the checks performed on the WRCS.

BIT Tests. The BIT tests made in the field shop are much the same as those made on the flight line. These checks are used to help confirm the fact that there is a malfunction in the LRU which has been turned in for repair action. The checks are also used in localizing the trouble within the defective LRU. Since these tests have been designed to check the overall operation of the system, they serve as an excellent way of localizing and verifying a malfunctioning component.

After hooking up the LRU to the test bench and performing a test bench self-test, complete the BIT tests in their entirety and record the mode test and the type and magnitude of failure. Then refer to the section on trouble analysis to isolate faults or continue with the operational mode tests. Each LRU has its own separate trouble analysis and maintenance section.

Operational Mode Tests. These tests are also performed on the test bench in the shop and are sometimes referred to as performance verification checks. They verify whether an LRU is or is not in an operational condition. The performance verification checks also indicate whether alignment and adjustment of the components under test are necessary or not.

Exercises (A40):

1. BIT tests can be performed on the flight line or in the shop, but those performed in the shop are different from those performed on the flight line. True or false.

2. What are the two shop tests that are performed on the WRCS?

A41. Distinguish between true and false statements concerning maintenance actions to take when troubleshooting for the WRCS.

Trouble Analysis. As mentioned previously, each LRU has its own trouble analysis section with system functional diagrams, unit schematics, and module schematics provided to aid the maintenance technician in isolating a malfunction.

The ballistics computer test bench has capabilities for patching out the subassemblies. This facilitates alignment, adjustment, and visual observation of internal parts. In addition, each section has figures and directions for disassembly and assembly instructions. Integration scaling tests are provided as a further aid to isolating malfunctions. Procedures for these tests are outlined in the checkout section of the TO.

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Exercises (A41):

1. The ballistics computer has capabilities for patching out subassemblies so that you may observe and adjust parts not normally accessible. True or false.

2. For information to aid in isolating a malfunction in the WRCS, you would look under integration scaling tests in the appropriate TO. True or false.

3. LRUs do not require maintenance because they are trouble free. True or false.

A42. Cite keypoints to remember in performing adjustments and alignments.

Adjustments and Alignments. One situation that you frequently run across when adjusting and aligning the system is the dependence of one adjustment on another. For example, in the target finding/offset bombing BIT mode, as given in the TO, you will find that step *d* reads, "Repeat step *c* until indications are within tolerance." Step 2 reads, "adjust along track and then cross track." We are to adjust the along track within limits and then adjust the cross track within limits. The next step says repeat this procedure. This action is necessary because adjusting the cross track will affect the along track and vice versa.

Now let us look at another situation that may arise in regard to adjustments. Assume that you have removed a defective LRU (ballistics computer) from the aircraft and sent it to the shop for repair. In return, you have received a replacement LRU, which has been checked out and aligned by the shop personnel. You then install the replacement LRU in the aircraft; however, you have one more job to do before you have cleared the trouble. You must check out the system and make sure that the system alignment is satisfactory. Placing a previously aligned LRU in another system can cause problems if the system alignment is not checked. This means that although an LRU has been aligned in the shop, it should be checked after it is installed in the aircraft; then aligned or adjusted if necessary. A common flight line term for this action is "marry the computer to the system." This is particularly important in analog computer systems where half of the servo system is in the control panel and the other half is in the computer. Sometimes this marriage can take place in the field shop and a complete system is reinstalled. Regardless of where it is done, the two parts of the servo system must be matched.

If, when you are making any of the system adjustments, you cannot locate and identify a test point or an adjustment potentiometer, refer to the component location for the particular LRU on printed circuit board.

Exercises (A42):

1. When you are making system adjustments, how can you locate a specific test point?

2. When you have installed a replacement LRU in the aircraft, what is your next step?

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ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

A01 - 1. The computer set computes distance to go, distance left or right of a desired track, and track-angle error.
A01 - 2. Navigational computer, control indicator, auxiliary cross-track control indicator, and air navigation multiple indicator.
A01 - 3. Information fed to the computer comes from a drift-angle groundspeed sensor (Doppler set).
A01 - 4. The track-error angle is displayed by the air navigation multiple indicator.
A01 - 5. Groundspeed data is supplied to the computer as a series of pulses whose frequency is proportional to the aircraft groundspeed.
A01 - 6. Distance to go is computed by subtracting along-track data from a preset value.
A01 - 7. The control indicator and the air navigation multiple indicator display distance to go.
A01 - 8. Cross-track data is fed to the auxiliary cross-track control indicator and to the control indicator.

A02 - 1. The sine function is used to compute cross track.
A02 - 2. The cosine function is used to compute distance to go.
A02 - 3. 10.
A02 - 4. 100.
A02 - 5. Adding "sense" to along-track and cross-track data means to determine if there should be an increase or decrease in the distance to go and if the cross track is left or right of the desired track.

A03 - 1. The resolver circuit generates the sine and cosine gate signals.
A03 - 2. A multiar operates when its two input voltages are equal.
A03 - 3. A multiar is used to trigger a flip-flop.
A03 - 4. The clock flip-flop circuit causes the high-voltage switch to change states.
A03 - 5. The PNP multiar fires and causes the clock flip-flop to change the high-voltage switch. The NPN multiar fires next to flip the clock flip-flop which again changes the high-voltage switch.
A03 - 6. The setting of the sine-cosine potentiometer determines when the sine-cosine multiars operate.
A03 - 7. The first pulse from a multiar is used.
A03 - 8. A PNP multiar detects coincidence between a fixed voltage and an increasing voltage. An NPN multiar detects coincidence between a fixed voltage and a decreasing voltage.
A03 - 9. The output from the high-voltage switch is a symmetrical square wave at 16-Hz rate and -50 volts amplitude.

A04 - 1. The Schmitt trigger circuit, with the delay gates, directs the sine and cosine signals to the along-track and cross-track binaries.
A04 - 2. The gate circuits insure that the beginning of the sine and cosine gate actions are in coincidence.
A04 - 3. 2.5 milliseconds.

A05 - 1. A tri-binary is a three-stage counter.
A05 - 2. There are two output pulses.
A05 - 3. The lengths of the sine and cosine gates are reduced by increasing the amplitude of the high-voltage switch output voltage. This is done by shunting a resistor in the power supply.

A06 - 1. The actuator circuit provides power amplification to drive the mechanical counters.
A06 - 2. The output of Q7 is applied to the base of Q4.
A06 - 3. Q4 and Q2 make up the Schmitt trigger.
A06 - 4. Q6.

A07 - 1. R3 provides negative feedback to provide system stabilization.
A07 - 2. The high input impedance of Q1 prevents current from flowing in the synchro system, thereby protecting the system.

A08 - 1. The motor turns the track resolver shaft that drives the sine-cosine potentiometer and the switches and cams. The amplifier provides control and power for the motor.
A08 - 2. The track resolver drive gives the "sense" to the output pulses.
A08 - 3. With this heading, the plane is flying away from the desired destination, so the distance to go increases, and the distance cross-track is left to the desired track.

A09 - 1. Full-wave rectification is used.
A09 - 2. The regulator controls the ratio between -30 volts and -50 volts. Since these are used in the resolver for timing, their ratio must remain constant.
A09 - 3. The heat sink is necessary because of the power dissipation of the output transistors in the servoamplifier.

A10 - 1. The distance to go is computed by adding or subtracting from a number preset in the distance-to-go counter.
A10 - 2. There will be no switching, since automatic switching will not switch to an empty stage.
A10 - 3. An increase in the counter causes the main cam to rotate counterclockwise.
A10 - 4. The cross-track assembly displays cross-track distance information on a counter.

A11 - 1. The auxiliary cross-track control indicator counts.
A11 - 2. The drop switch energizes relays in the sine or cosine binaries, and the division ratio of the feedback circuit is changed.

A12 - 1. When terminals 2 and 4 of the control winding are at the same potential, there is no voltage drop across the motor MG1; thus, MG1 stops and the counters cease to turn.
A12 - 2. False.
A12 - 3. CT1.
A12 - 4. CR5 and CR6 limit the voltage from CT1.

A13 - 1. The audio oscillator simulates the input of the Doppler sensor.

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A14 - 1. If the voltage between A–4, A–5, and A–6 does not vary to 10 volts during a malfunction in the multiple indicator, the multiple indicator is faulty. The procedure directs you to step 8 for further checks.

A15 - 1. T.
A15 - 2. T.
A15 - 3. T.
A15 - 4. F.

CHAPTER 2

A16 - 1. The Computer-Control, the Amplifier Computer, and the Groundspeed Indicator.
A16 - 2. The length of time that power has been applied to the INS system.
A16 - 3. It is used in updating the magnetic variation counter.

A17 - 1. (1) c.
(2) a.
(3) c.
(4) b.
(5) a.

A18 - 1. The magnetic variation, windspeed, true wind direction, and present latitude and longitude.
A18 - 2. Magnetic heading and variation.
A18 - 3. True airspeed, true heading, and N-S and E-W windspeeds.
A18 - 4. 1 minute of latitude.
A18 - 5. in B807.
A18 - 6. Groundspeed, ground track, and drift angle.

A19 - 1. The geographic North Pole, present position of the aircraft, and preselected TGT–1 or TGT–2.
A19 - 2. 2B2.
A19 - 3. The difference between target longitude and present-position longitude.
A19 - 4. 2B1.
A19 - 5. D is the great circle distance and C_A is the great circle bearing.
A19 - 6. B803.
A19 - 7. TGT–1, latitude resolver LT1 is replaced by the TGT–2 latitude resolver LT2, and the TGT–1 present-position longitude difference resolver (LOT1 - LO_{DR}) is replaced by the TGT–2 present-position longitude difference resolver LOT2.

A20 - 1. In the Amplifier Computer unit.
A20 - 2. A803 drives the range servo, and A806 drives the bearing servo.
A20 - 3. Provide power amplification sufficient to drive the servomechanisms in the computer.

CHAPTER 3

A21 - 1. This positions the wiper of 2R77.
A21 - 2. 2B13 yields the N-S and E-W components of windspeed.
A21 - 3. 2R45 nulls out the TAS input from the data computer as the output shaft of 2B24 assumes a position corresponding to true airspeed.
A21 - 4. A cam corrector mechanism is provided in the TAS shaft.
A21 - 5. In 2B21 by adding magnetic variation.
A21 - 6. Resolver 2B14.
A21 - 7. In resolver B801.
A21 - 8. 2B6, the latitude clutch, 2B7, 2B15, and A805.
A21 - 9. Relay K801 makes it possible for servoamplifier A805 to alternately drive 2B6 and 2B8.

A22 - 1. The B2 in the INS set, amplifier A807C, amplifier A802A, motor B2008, secant corrector, and 2B27.
A22 - 2. The secant corrector does not affect the positioning of the longitude counter in the inertial mode. It affects only the gain of the servo loop.
A22 - 3. It can be obtained from the stator of 2B27.

A23 - 1. Resolves target latitude into the sine and cosine of target latitude.
A23 - 2. The difference between target longitude and present-position longitude.
A23 - 3. It is combined with the the output of 2B19 to produce sin D cos C_A.
A23 - 4. Resolver B803 positions, through servomotor B804, the rotor of B808, thereby producing a signal representing C_A. It also positions, through servomotor B805, the distance-to-go shaft.

A24 - 1. To allow the radar pilot to continuously update the magnetic variation as set by the variation control knob.
A24 - 2. The variation sync meter is centered by operating the variation knob in the appropriate direction.

A25 - 1. Adjustments are made on B2021 in accordance with the "NOTE" relative to the check 5c in figure 3-2.

A26 - 1. False.
A26 - 2. True.
A26 - 3. False.

CHAPTER 4

A27 - 1. Six operational modes.
A27 - 2. Laydown, dive laydown, and offset bomb mode.
A27 - 3. In the dive laydown mode, radar is used to insert range to target, whereas in the laydown mode range to target is manually inserted.
A27 - 4. In the target find mode, no bomb release signal is generated.
A27 - 5. Offset bomb mode and target find mode use a checkpoint to assist the pilot in flying to a target that is not radar identificable.
A27 - 6. AGM–45 mode.
A27 - 7. Offset bomb mode and target find mode.
A27 - 8. The dive toss mode allows the aircraft to clear the effects of a low-drag-type bomb.

A28 - 1. To determine the status of the WRCS.
A28 - 2. If the WRCS solves a BIT problem in 17 seconds, the NO-GO indicator will illuminate.

A29 - 1. Ballistics computer, computer control, and computer-cursor control.
A29 - 2. To solve the bombing problem for the various modes of the WRCS.
A29 - 3. The computer control contains the controls necessary for inserting target distance, target altitude or range, drag coefficient, and release data. The computer-cursor control controls the cursors in various modes of the WRCS to cause solution of the bombing problem.

A30 - 1. A/C vertical acceleration, $\pm V_g$, N-S vel, ± vertical vel, V_t, altitude, climb angle, TH, TR, power-interrupt signal, pitch angle, and navigate mode signal.
A30 - 2. All power is removed from the WRCS.

A31 - 1. To give the pilot a reticle image for a visual sight to fire guns, rockets, launch missiles, or release bombs.
A31 - 2. Laydown mode and AGM–45 missile mode.
A31 - 3. Drift signal.

A32 - 1. 250-VDC slant range excitation, cross-track range excitation, and radar slant range.
A32 - 2. WRCS slant range and cross-track range.

A33 - 1. Mode selection control signal.
A33 - 2. Pickle signal.

A34 - 1. On 1J2, pin t.

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A34 - 2. To insert the target range into the computer.
A34 - 3. + release range, − target range, + release advance, and + delay signal.
A34 - 4. When the system is in LAYDOWN position and the BIT switch is not depressed.
A34 - 5. The range to go to target.
A34 - 6. When the range to go to target equals the release range minus the target range.
A34 - 7. To prevent a release signal from being generated when the INS is inoperative.

A35 - 1. Release range, release advance, and rack delay time.
A35 - 2. 1J3, pin U.
A35 - 3. 1J2, pins p, BB, and AA.
A35 - 4. Ground range to target.

A36 - 1. Servo A7.
A36 - 2. 1J3, pins s and U.
A36 - 3. R2A in servo A10.
A36 - 4. The capacitive feedback inserted when K42 is energized.
A36 - 5. To furnish a signal representing ejection velocity.

A37 - 1. No release signal is generated in target find mode.
A37 - 2. True heading, velocity north, velocity east, true ground track, altitude, groundspeed, release advance, release range, target altitude, and target distance north.

A38 - 1. Altitude, climb angle, groundspeed, total velocity, target altitude, and release advance.
A38 - 2. The angle of attack indexer lights.
A38 - 3. Servo A7.
A38 - 4. When R_g becomes equal to R_{mis} minus $V_g T_a$ and R_b.

A39 - 1. K28, K29, K31, K32, K33, K35, K37, K40, K66.
A39 - 2. K41.
A39 - 3. 2 seconds.
A39 - 4. K59.
A39 - 5. K57.
A39 - 6. To deenergize the time-delay relay.

A40 - 1. False.
A40 - 2. BIT and operational mode tests.

A41 - 1. True.
A41 - 2. True.
A41 - 3. False.

A42 - 1. By referring to the component location chart.
A42 - 2. To check out the system and make sure that the system alignment is satisfactory.

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